A COMPARISON OF STUDENTS' INTEREST IN STEM ACROSS SCIENCE STANDARD TYPES

by

Brienne Kylie May

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

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Dedication

This dissertation is dedicated to my biggest cheerleader, my husband Steve, who never let me lose sight of my goal and to my daughter, Fiana, who was born right in the middle of my doctoral journey and held the position of my greatest motivator from day one.

Acknowledgments

I would like to thank my dissertation chair, Dr. Jillian Wendt for her patience, feedback, and endless encouragement and my committee member Dr. Michelle Barthlow for her guidance and expertise. I would also like to thank the students, teachers, principals, and superintendents who contributed to my data collection during a very difficult school year.

Abstract

The purpose of this study is to determine whether students enrolled in ninth and 10th grade science classes implementing the Next Generation Science Standards (NGSS) have significantly different interests in science, technology, engineering, and math (STEM) compared to students enrolled in classes structured around alternate state standards unrelated to the NGSS. The study also investigates how such interests may differ among genders. No research has been conducted to date to determine the potential effects of the NGSS on student interest in STEM or whether these standards impact student interest at all. This study utilizes a causal-comparative design to study the potential effects of science standard type on student interest in STEM. The study participants include ninth and 10th grade students enrolled in general science classes from public school districts in NGSS and non-NGSS classrooms in the United States. Interest was measured using the Likert-style Science Technology Engineering and Math Career Interest Survey. A two-way multivariate analysis of variance (MANOVA) was used to compare the mean scores derived from the instrument regarding overall science interest, individual STEM subscales, and gender variations across the participating classrooms. The results of the study indicate a statistically significant difference between the measures on the science and technology subscales as well as the overall STEM scores based on science standard type. No significant difference was found, however, for the mathematics or engineering subscales or for student gender.

Keywords: STEM, Next Generation Science Standards, science interest, gender differences

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List of Abbreviations

Crosscutting Concepts (CC)

Disciplinary Core Ideas (DCI)

English Language Arts (ELA)

National Research Council (NRC)

National Science Teacher Association (NSTA)

Next Generation Science Standards (NGSS)

Regional Educational Laboratory (REL)

Science and Engineering Practices (SEP)

Science, technology, engineering, and mathematics (STEM)

CHAPTER ONE: INTRODUCTION

Overview

This chapter begins with a discussion concerning the development, implementation, and goals of the Next Generation Science Standards (NGSS) and how these standards relate to research. The standards and their evolution are related to research that has been conducted on science interest and the best practices within science education over the past sixty years. This previous research orients the problem of the current research and the significance of the present study.

Background

Student interest in science has been a major topic of inquiry for researchers over the past half century, when declining interest in science from elementary to high school was first observed in the 1960s (Bryant et al., 2013; Van Griethuijsen et al., 2014; Weisgerber, 1961; Wiebe, Unfried, & Faber, 2018). Furthermore, inquiries revealed alarming trends that included a stark discrepancy between male and female students' interest in science (Cunningham, Hoyer, & Sparks, 2015; Kerr, 2016; Valenti et al., 2016). These same patterns continue today, and the effects of gender disparity, in particular, can be felt long past high school graduation. As of 2017, women held only 30% of STEM degrees (Noonan, 2017). The U.S. census data from 2019 reveal that women occupy a scant 27% of all STEM careers despite their almost equal participation in both postsecondary education and the workforce (Martinze & Christnacht, 2021). With researchers continuing to seek solutions, the most recent national standards, the Next Generation Science Standards (NGSS), were created over a span of 3 years by a team of interdisciplinary writers, reviewers, and developers (Next Generation Science Standards, 2011). The NGSS were grounded in the growing body of research which identified a stark decline in both interest in and best practices for engaging students in science learning. The NGSS were designed, in part, to address the declining interest in science and the disproportionate gender participation in it. The standards are rooted in inquiry and performance-based assessments that consider the needs of diverse learners and are aligned to current science education ideals.

Twenty-six states worked in partnership with organizations and experts to assist in creating the standards (NGSS, 2011), which were ultimately adopted by 19 states and the District of Columbia (NSTA, 2019). In addition to the 19 states that adopted the standards, 21 other states opted for a unique set of standards aligned with the same recommendations that were used to inform the NGSS (NSTA, 2019). Across the 19 states that formally adopted NGSS and the 21 others with similar, albeit independent, standards, 84% of U.S. students are taught science utilizing standards based on the reports of the National Research Council (NRC; NSTA, 2019). Notably, however, 16% of students are not taught using the NGSS or similar standards including those students enrolled in public schools in Pennsylvania, Ohio, Texas, Minnesota, Virginia, North Carolina, Florida, and Alaska (NSTA, 2019).

Defining the NGSS

The partnership between lawmakers, scientists, researchers, and teachers led to the NGSS, which are based on researched and vetted best practices and were developed to promote authentic science exploration in a manner that mimics the experiences of scientists in the field (Regional Educational Laboratory Mid-Atlantic, 2014). Based on the 2012 work, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas,* and an evolving body of research examining how students learn science, the NGSS are a collection of standards situated within modern, cross-curricular experiences aligned to corresponding Common Core Math and English Language Arts (ELA) standards (Bybee, 2014; NRC, 2012; REL, 2014).

Previous standards relied heavily on the accrual of factual knowledge, but the NGSS remain unique in approaching science through a focus on the interconnectedness of science disciplines that is designed to reflect authentic scientific exploration (REL, 2014). Topics such as photosynthesis, gas laws, and the water cycle are not learned in a vacuum, existing uninspired by and unrelated to other topics. Instead, topics are presented within a holistic curriculum where topics are understood under a larger umbrella, allowing them to be explored in a context in which chemistry, physics, life, and Earth science concepts continually affect one another. This interdisciplinary approach provides for a focus on depth rather than fact memorization (REL, 2014).

The shift from fact-based education was explicitly recommended in the NRC's *Framework* (2012), stating:

> The framework is motivated in part by a growing national consensus around the need for greater coherence—that is, a sense of unity—in K-12 science education. Too often, standards are long lists of detailed and disconnected facts … Not only is such an approach alienating to young people, but it can also leave them with just fragments of knowledge and little sense of the creative achievements of science, its inherent logic and consistency, and its universality. Moreover, that approach neglects the need for students to develop an understanding of the practices of science and engineering, which is as important to understanding science as knowledge of its content. (p. 10)

The NRC (2007) suggested that the overemphasis on factual knowledge and the scientific method that predated recent standards were a hinderance to both student growth and understanding science. Beginning at a young age, they argue, children construct their own knowledge of the world through interaction and observation (NRC, 2007). Children as young as first grade recognize basic principles of life, Earth, and physical science through their participation in the world (NRC, 2007). Based on this knowledge, educators have long advocated for science education that focuses on authentic practices in order to not only increase understanding of scientific facts and theories but also to produce a more science-literate population that can apply scientific understanding to common household and political discussions, such as those involving vaccinations, climate change, and genetic modification (NRC, 2007). Although not all students will pursue the sciences, the emphasis of practice over facts is intended to equip students for life beyond the classroom in any capacity in which they may encounter science.

Alignment of NGSS to Science Education Goals

The NGSS were designed to prepare students for college, careers, and citizenship, and leveraged decades of previous research on best practices to achieve these goals (REL, 2014; Januszyk, Miller, & Lee, 2016). In its *Framework*, the NRC calls for standards that are few in number, scientifically accurate, research based, and designed to maintain high expectations for all students, with consideration given to student diversity (NRC, 2012). These specifications stem from the NRC's (2012) intended goal of raising all students to be science literate, with an appreciation for and basic understanding of the domains of both natural and human-made science, thereby enabling them to be responsible consumers of information and advocates for scientific truth. The content of modern science education should, according to the NRC (2012), provide students with a sufficient background to explore the career of their choice, including those in the STEM disciplines. To achieve these goals, the *Framework* advocates that students develop deep, rich understandings of fewer key concepts that are built upon year after year, growing in complexity and relating to other important ideas within science disciplines (NRC, 2012). This shift from traditional fact-based standards (that included inquiry only in isolation) to a more integrated approach encourages students to demonstrate learning through practical and applicable means (Krajcik et al., 2014). The *Framework* facilitates this acquisition of knowledge and understanding through authentic exploration and the building of connections (NRC, 2012).

Science inquiry, however, is not a new concept in education, and the NGSS were not the first attempt at enacting change in the manner science is taught. In 1996, the National Science Education Standards were created by the NRC following the advice and guidelines outlined in the 1989 Science for All Americans and the 1993 Benchmarks for Science Literacy documents (Bybee, 2014). In the National Science Education Standards, inquiry was considered a favorable pedagogical practice but was withheld from being embedded because rigor traditionally referred to the explicit knowledge to be learned; the more facts, the higher the rigor (Pruitt, 2014). With NGSS, however, the inquiry is more than “hands-on” experimentation. It involves cognitive, social, and physical engagement (Huff, 2016). The NGSS took the ideas of what students should “know” and created performance assessments that enabled a well-rounded learning experience (Achieve, 2013). This emphasis on evolving knowledge to higher levels required reassessing the essentials of learning. Across disciplines, standards were cut, modified, and combined in a manner that deviated from the traditional course of study, providing more opportunity for depth of understanding while simultaneously highlighting changes and advances in scientific discovery (Bowman & Govett, 2015). Huff (2016) described the rationale of condensing the content of knowledge in favor of the depth of study by stating, “information is ubiquitous—virtually at the touch—and an important role of science education is not to teach students ‘all the facts’ but rather prepare them with sufficient core knowledge so they can later acquire additional information on their own” (p. 33).

Design of the Next Generation Science Standards

The standards encompass three dimensions: disciplinary core ideas (DCI), science and engineering practices (SEP), and crosscutting concepts (CC). These three dimensions complement each other and facilitate the interdisciplinary goal promoted by the NRC (Bybee, 2014; REL, 2014).

Disciplinary core ideas are core principles within each scientific discipline that are considered by the authors to be necessary for thinking about, analyzing, and reasoning through problems within the discipline (Duncan & Cavera, 2015). Each discipline—physical science, life science, Earth and space science, and engineering—is limited to four or fewer DCI (Duncan et al., 2015). This intentional restriction of DCI allows teachers to focus on depth and genuine understanding. Duncan et al. (2015) note, however, that within science education, depth does not refer to teaching the minute, explicit details but instead refers to the student's ability to make connections and develop firm understandings across concepts and disciplines. An accurate, practical, and meaningful understanding of phenomena requires more than a collection of loosely related facts. Instead, true understanding is broad, inclusive, and thorough, analogous to a system of knowledge in which each idea is connected to other concepts (Kelp, 2015). In this way, students learn to see scientific domains as they exist in the real world: interconnected and codependent. With the NGSS, the goal of science learning is to develop a conceptual understanding that analyzes the "hows" and the "whys" of science phenomena (Barber, 2018).

Science and engineering practices, the second dimension, prioritize the utilization of inquiry as a tool to explore the cores of scientific concepts (Duncan et al., 2015). For example, through inquiry, students can come to understand that cold water is more dense than hot water as they view red-dyed hot water float precariously atop blue-colored cold water within a container.

The SEP, however, stop short of engaging students in the *why* component (Duncan et al., 2015). The SEP are designed to ensure students engage in multiple practices rather than merely one, and participate in analyzing these practices to truly develop an understanding of scientific phenomena. The SEP require students to consider all variables, to question which elements should be included in a valid experiment, and to determine what should be regarded as evidence (Duncan et al., 2015). Furthermore, students are urged to consider how these factors vary from experiment to experiment, eliminating the once-popular belief that there is one correct way to conduct an experiment (Duncan et al., 2015). This focus on practice and discussion situates scientific discovery within a community—the scientific community, the classroom community, and even the dynamics within a lab group—emphasizing the collaborative component of science exploration (Duncan et al., 2015).

The third dimension, CC, provides students with an opportunity to view scientific analysis and experimentation through different lenses (Duncan et al., 2015). The CC allow students to dissect and analyze multiple angles of the same principle, just as scientists would in an authentic investigation (Duncan et al., 2015). Duncan et al., (2015) described CC as “thinking tools students can use when trying to understand phenomena in the world around us” (p. 54). Crosscutting concepts include seven components: patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change (National Science Teacher Association [NSTA], n.d.). The NSTA advocates for the explicit instruction of these concepts “because they provide an organizational schema for interrelating knowledge from various science fields into a coherent and scientifically based view of the world” (NSTA, n.d., para. 1).

Addressing the Needs of Diverse Learners

One of the hallmarks of NGSS is its “All Standards, All Students” initiative, which addresses the glaring achievement gap for traditionally underrepresented students (Strachan, 2017). The initiative, created by the NGSS Diversity and Equity Team, enhanced accessibility and considered the diversity of students across the United States in terms of background, gender, language, and race (NGSS, 2013). The team was tasked with reviewing the standards for potential bias, infusing the NGSS Appendices with themes addressing diversity and equity, and producing the NGSS Appendix D document, which addresses the issue of best practices with traditionally underrepresented learners (Okhee et al., 2014).

In a similar display of commitment to all learners, the NGSS emphasizes the human nature of science by giving credit to men and women of all ethnic backgrounds (Okhee et al., 2014). Through this effort, attention is shifted from the traditional view of scientists as Western European men to acknowledge the global contributions of people of all races to the body of scientific knowledge. For instance, the inclusion of engineering as a goal for all students provides opportunities for teachers to emphasize the contributions of non-Western civilizations credited with advanced engineering techniques. Such civilizations include indigenous populations such as the Aztecs and Incans, as well as the Arabic, Egyptian, and Chinese cultures, whose early achievements in engineering left lasting ns on the world of science, math, and art (Januszyk et al., 2016).

To address the needs of diverse learners, the NGSS recommend pedagogical techniques that make the content accessible to all students (Okhee et al., 2014). The recommendations include:

1. Bridging students' prior knowledge with content using culturally relevant pedagogy
2. Accessing community resources and addressing societal issues relevant to students
3. Presenting material through multimodal experiences
4. Creating a culture in which science is well respected and students have the opportunity to engage with role models of similar backgrounds (Strachan, 2017; Januszyk et al., 2016)

Of the traditionally underrepresented populations with the potential to benefit from the pedagogical practices of the NGSS, one of the most notable is the female population. As girls progress from elementary to middle and high school, their interest in science wanes in a manner that is not observable in their male peers (Cunningham et al., 2015; Kerr, 2016; Valenti et al., 2016). As female interest rapidly declines, male and female participation in STEM activities diverges as students age through middle and high school (Brown, Ernst, Clark, DeLuca, & Kelly, 2017; Sahin et al., 2015; Valenti et al., 2016; Wang & Degol, 2017). The disparity of interest between male and female students exists despite statistics indicating that, by high school, girls enroll in an equal or greater proportion of math and science courses compared to their male classmates (Cunningham et al., 2015).

As students age out of high school and into the work force, the impact of the disproportionate interest of females and males in science becomes clear. Although women earn nearly half of all degrees attained, they account for only 30% of STEM degrees (National Science Foundation, 2019; Noonan, 2017). Moreover, the percentage of woman who hold degrees in STEM areas that include computer science, mathematics, and statistics, has decreased alarmingly over the previous 20 years (National Science Foundation, 2019). The lack of female interest in science and the subsequent underrepresentation of females in the field has a strong effect on society as a whole. Indeed, several researchers have argued that the fields of STEM and the products that derive from modern innovation, creative problem solving, and collaboration are suffering from the lack of female participation (Albrechsten, 2018; Gokhale et al., 2015).

The pedagogical practices promoted by the NGSS, however, closely mirror research-based practices, which have been found to increase interest in science among female students. For example, girls have indicated higher interest in STEM when the courses address real-world problems through authentic methods and meaningful exploration, a major cornerstone of the practices outlined in the NGSS (Weber, 2012; Brown et al., 2017).

Criticisms of NGSS

While NGSS have incorporated many of the values prescribed by prior science-education research, they have received criticism. In an effort to focus on depth, some researchers have argued that the standards have removed too much of the original content (Lontok et al., 2015; Slater & Slater, 2015). The removal of content has resulted in lower volumes of substance and general knowledge in specific disciplines. Lontok et al. (2015) argued that the standards cover more content than may be initially apparent, but in order to find complete standards, teachers must view the standards alongside supporting documents such as DCI and CC. Teachers who do not, they contend, are in danger of omitting valuable information and incompletely teaching the content (Lontok et al., 2015). The performance-based nature of the standards has raised questions among experts in the field as well. Hoeg and Bencze (2017) asserted that the standards overemphasize process skills such as engineering practices, which has made the standards impractical for the average student who does not plan on pursuing a career in STEM.

Alternatively, the NRC argues that the inclusion of SEP in science education provides insight into both the impact of humans in the world of science, and the exploration of science as both a human and natural phenomenon (NRC, 2012). Lederman and Lederman (2016) have also cast doubt on the intense focus on science practices, stating that these application skills have little meaning if not used in conjunction with discussions regarding the meaning of results and the process of developing scientific knowledge (Lederman & Lederman, 2016).

Theoretical Background

Constructivist theories such as social learning theory, discovery learning, and situated learning theory are the guiding theories in science-education research. Constructivist theories describe learning as a process that occurs over time in natural settings through reaching beyond current levels of functioning (Brown et al., 1989; Vygotsky, 1978). Though different, situated learning, discovery learning, and social learning theories all stem from the research-based belief that students must construct their own learning through their experiences, as opposed to passively receiving knowledge from an instructor (Taylor, 2015). Constructivist theories both influence the culture of science-education policy in the era of the NGSS, and provide a basis for inquiry- and experience-based learning strategies to replace textbook-reliant science education. A growing body of research supports the claim that constructivist methodologies, discovery learning, and the inclusion of inquiry learning as a primary pedagogical practice may lead to an increase in science interest, which, in turn, encourages more students to pursue careers in STEM fields (Hacieminoglu, 2015; Odom, 2013; Akcay, 2015). Furthermore, constructivist theories ground the present study by providing a lens through which the guiding principles of the NGSS can be analyzed regarding the possible impact they may have on the problem of student interest in science-related subjects.

Similar studies have also used these same constructivist principles to ground their research. In one study, researchers utilized principles from the NRC *Framework* to increase female interest in STEM through cross-curricular afterschool activities (Nation et al., 2019). Upper-elementary-aged girls interviewed female scientists and used writing and art to communicate their interviews to others (Nation et al., 2019). The researchers found that the girls' interests increased as they gradually perceived science to be a real-world experience in which having the correct answer is a far lesser goal than developing an understanding of the world (Nation et al., 2019). The study was grounded in constructivist theories as well as research-based science practices, leading students to develop their own understanding of science through diverse experiences and exploration.

In another study, researchers Bystydzienski et al. (2015) used a three-year afterschool intervention program to increase high school girls' interest in STEM. The study's foundation was grounded in providing girls with opportunities to meet engineers, explore working laboratories, and engage in hands-on experiences akin to research being conducted in the field (Bystydzienski et al., 2015). The researchers determined that the use of the intervention program not only increased interest, but sustained student interest through college and career.

A third study, which most closely resembles the methodology of the present research, implemented a causal-comparative design to identify the impact of STEM exposure via an annual exposition on student interest in STEM domains (Kurz et al., 2015). In this study, researchers Kurz et al. (2015) administered surveys to students in school districts that either did or did not participate in the annual expo. The authors theorized that the exposure to hands-on experiences would produce positive effects, particularly for girls (Kurz, et al., 2015).

Problem Statement

Although researchers have investigated methods of increasing student interest in science (Ercan, 2014; Hacieminoglu, 2015; Hasni, 2015; Korur et al., 2016; Odom, 2013; Vervaeke & Ferraro, 2013; Wyss, 2013), and specifically that of female students (Albrechsten 2018; Beede et al., 2011; Gokhale et al., 2015; Hasni, 2015; Lane et al., 2012; Makarova & Herzog, 2015; Phelan et al., 2017; Vervaeke & Ferraro, 2013; Wang & Degol, 2017; Wyss, 2013), research has not yet been conducted to determine whether students in NGSS classrooms have a higher level of interest in science compared to those in classrooms utilizing standards that are not aligned with the NGSS nor NRC recommendations. Notably, the United States Department of Education (2010) and the National Science and Technology Council (Executive Office of the President, 2018) have underscored the importance of increasing science interest among students, citing it as a major factor in determining future career prospects. Moreover, research has indicated that interest in science generally tends to be lower for Western students compared to students in other parts of the world (Van Griethuijsen et al., 2014; Senler, 2015). The previously mentioned steady decrease in interest in science from elementary to high school (Bryant, et al., 2013) therefore becomes problematic for American students aspiring to remain competitive in an increasingly technological and global modern society.

The lack of science interest is even more profound for the female population. Girls continue to be underrepresented in STEM fields and tend to have lower interest, self-perception, and an overall poorer attitude toward science (Cunningham et al., 2015; Kerr, 2016;). Researchers Gokhale et al. (2015) emphasize the importance of research into female science interest in order to increase the number of qualified women in STEM fields and thereby add to the diversity of ideas within the field.

While the question of the effectiveness of the NGSS at increasing science interest remains unanswered, research suggests that "doing science" in the form of real-world problem solving and authentic, hands-on experiences—much like the practices advocated by the NGSS—is highly correlated with increasing interest in science (Erdogan & Stuessy, 2015; Hacieminoglu, 2015; Odom, 2013). The problem is that studies have not yet determined whether students in NGSS classrooms demonstrate a significant difference in science interest compared to those in classrooms which have not adopted the NGSS. Moreover, research has not concluded whether the NGSS has had positive impacts on female students' interest in science, which may have a profound impact on efforts to broaden participation.

Purpose Statement

The present research utilizes a causal-comparative research design to determine whether students in classrooms applying the NGSS have a higher level of interest in STEM disciplines compared to students attending schools implementing other standards. Furthermore, the study places a specific emphasis on the potential differences between male and female students. The research examines the effects of the independent variables and the dependent variables as determined by the STEM-CIS. The independent variables in the study are the science standards types, identified as NGSS or non-NGSS, and the student genders, listed as male or female. The dependent variables are measures of self-reported interest in science, technology, engineering, math, and STEM overall, as quantified by scores on the STEM-CIS. Interest has been defined by researchers as a psychological feature having both internal and external influencing factors, often quantified by self-report measures (Oshborne et al., 2003). The present study quantifies interest through a combination of questions involving the self-reporting of self-efficacy, personal goals, outcome expectations, and contextual support (Kier et al., 2014). The present research focuses on assessing the interest of students in public high schools who have either participated in the NGSS curriculum or have participated in traditional state science curricula during their elementary and middle school science experiences. The sample population was drawn from students enrolled in high schools in Pennsylvania.

Significance of the Study

A review of the literature indicates both a decline in science interest from elementary school to high school (Bryant et al., 2013; Van Griethuijsen et al., 2014) and a consistent discrepancy in the interest of male and female students toward science (Cunningham et al., 2015; Kerr, 2016; Valenti et al., 2016). Over the past 60 years, researchers have indicated methods of increasing student interest in science, including student-centered teaching (Akcay, 2015), inclusion of student interests (Ercan, 2014; Korur et al., 2016), and emphasizing process and growth over product (Schmidt et al., 2017). The present study adds to the existing body of research by investigating the potential impacts of the NGSS on student interest in science. While research has suggested the NGSS increase student interest through such methods and practices as hands-on engineering activities (Bethke et al., 2013) and culturally relevant pedagogy (Hasni, 2015; Dodo Seriki, 2018), research remains inconclusive regarding whether the implementation of the NGSS in classrooms has significantly impacted science interest.

The study was conducted using a sample population of students enrolled in public high schools in Pennsylvania. Pennsylvania, unlike many other states, has neither produced new standards based on the advice of the NRC nor adopted the NGSS (NSTA, 2019). Rather, schools in Pennsylvania use standards which were designed throughout the 1990s and officially adopted in 2002 (Remington, 2018). Critics of Pennsylvania’s current science standards argue that numerous historic scientific accomplishments have occurred since the introduction of the

Pennsylvania science standards including the widespread availability of cell phones and the internet (Murphy, 2019; Remington, 2018). Some districts in Pennsylvania, however, have independently adopted the NGSS ahead of official state changes (Heitin, 2015). The present study seeks to determine whether the newly implemented NGSS standards influence student interest in science compared to science standards that are not based on the NRC *Framework*.

Research Question

The research question for this study is as follows:

RQ: Is there a difference between students' interest scores in science, technology, engineering, mathematics and overall interest in STEM, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not adopted the NGSS based on the gender of the student?

Definitions

1. *Gender* – According to the American Psychological Association, gender is the state of being male, female, or neither male nor female (American Psychological Association, 2015). Gender differs from sex in that sex is related to the biological components of the male and female, while gender refers to psychological and sociological factors (American Psychological Association, 2015).
2. *Interest* – Interest is defined as an intrinsic motivation to engage in content and activities for the sake of individual pursuit (Siliva, 2001).
3. *Standards* – According to the United States Department of Education, standards are a set of expectations for student knowledge established for all students in all states that are designed to ensure students will not require remedial education in postsecondary college and career pursuits (U.S. Department of Education, n.d.).

4. *STEM education* – STEM education refers to the integration of specific skills from mathematics and science with a product that utilizes the creativity and teamwork required by engineering (Shaughnessy, 2013).

CHAPTER TWO: LITERATURE REVIEW

Overview

Interest, as it pertains to science, has long been studied by researchers concerned about the available pool of qualified science candidates. Researchers have built upon decades of studies to determine methods of increasing science interest, particularly for traditionally underrepresented populations, such as women. In this literature review, a series of seminal and empirical studies are analyzed to frame the problem of science interest within both contemporary and historical frameworks as well as through the lens of theoretical dispositions juxtaposed with more practical applications. A historical perspective highlights the longevity of the modern problem of science interest, while providing context for the methods and studies that have influenced those current practices intended to increase science interest among students. The literature review concludes with a discussion of best practices and how these practices relate to contemporary efforts in science education.

Introduction

For decades, researchers and teachers, realizing the criticality of science to the advancement of society, have been exploring means to promote science interest in students around the world. With the goal of strengthening interest in science, researchers have sought to bring about change and increase the flow of individuals into the scientific fields through education.

Interest has long been studied by researchers concerned with declining numbers of students in STEM fields (Wiebe, Unfried, & Faber, 2018). Interest is part of the affective psychological domain and is identified as an intrinsic aspect of behavior that can be detected and studied through the self-reporting measures of participants (Ellis & Gerberich, 1947). According to Wiebe, Unfried, and Faber, interest fluctuates in young children, but gradually becomes fixed as children age into middle and high school.

A review of the literature indicates a consistent discrepancy between the interest of male and female students toward science (Catsambis, 1995; Cunningham et al., 2015; Eccles et al.,1993; George, 2006; Kerr, 2016; Shymansky & Kyle, 1988; Quinn & Lyons, 2011; Simkins et al., 2005; Simpson & Oliver, 1990; Valenti et al., 2016; Weinburgh, 1995). The research suggests, however, that constructivist methods, discovery learning, and inquiry-based practices may improve children's interest in science and thereby lead to an increased interest in STEM careers (Hacieminoglu, 2015; Odom, 2013). Derived from decades of research on best practices in science, the NGSS are based on constructivist, inquiry, and discovery principles which emphasize "doing" rather than "knowing" science. The present study seeks to determine the impact of the NGSS on science interest among male and female students in public high schools.

Theoretical Framework

The NGSS, with an emphasis on critical thinking, application, design, and discovery over more traditional, often passive, methods of learning, presents a foundation based on several theoretical constructs. In particular, many of the verbs included in the individual standards found in the NGSS directly relate to constructivist theories, including social learning theory, discovery-learning theory, and situated learning theory. Together, these theories construct a theoretical framework for the present study and indeed convey the influence of seminal works relating to active engagement, authentic tasks, and problem-based learning modalities that can be found in the NGSS.

Constructivist Theories

Constructivism represents the epistemological position that all individuals construct their own social realities and distinguish meanings from social interactions and situations that exist independently of the meaning derived by another individual (Gall et al., 2007). The connotation one individual infers from a social event may differ drastically from the significance another draws from the same event (Gall et al., 2007). In education, however, constructivism has come to take on a slightly different tone based on the foundations of its epistemological beginnings. In education, constructivism refers to the practice in which students build their own knowledge and understandings through exposure, inquiry, and investigation (McPhail, 2016). True constructivism shifts the focus in the classroom to meaning-making, problem solving, and the action of *knowing* over the possession of *knowledge* (McPhail, 2016).

As opposed to true, epistemological constructivism, students in constructivist science learning environments experiment and interact with concepts in order to arrive at validated scientific knowledge. A modern constructivist classroom more closely resembles the concept of social constructivism, in which individuals develop knowledge based on the experiences received within groups or communities (Taylor, 2015). In science, students constantly create, test, and revise theories based on data collected alongside their classmates (Peoples et al., 2014). Their experimentation, inquiries, and peer discussions are guided by a teacher to assist students in arriving at accurate conclusions (Peoples et al., 2014). In this style, students claim ownership over their knowledge as they have proven it for themselves. The constructivist method of knowledge acquisition goes beyond the tradition of simply relying on a teacher or textbook for information that students are expected to accept as factual with little first-hand evidence and no meaningful connections.

An early constructivist, Piaget, who conducted much of his work with his own young children, was one of the first theorists to radically shift the idea of science education from the perspective of the teacher (Taylor, 2015). Piaget posited that knowledge cannot be effectively transmitted through simply relaying facts from one person to another, or from teacher to student, but must be experienced in an authentic context (Piaget, 1953). According to Piaget (1971), "essential functions of the mind are formed by developing a foundation consisting of understanding and innovation and constructing reality" (Piaget, p. 27). Toward the end of the 20th century, these ideas eventually transformed into the belief that students should be educated in classrooms that embrace inquiry and discovery as primary means of knowledge acquisition (Taylor, 2015).

As recommended by the NRC, constructivism has been an essential learning theory embedded in science education since the 1990s (Colburn, 2000). Colburn (2000) referred to it as "science education's 'grand unifying theory'" (p. 9). Modern science classes currently incorporate a wide range of constructivist theories, including the findings of seminal works from leading theorists such as Piaget, Vygotsky, Bruner, and the researchers, Brown, Collins, and Duguid.

Social Learning Theory

Vygotsky's theory of social learning involves the notions that children develop through learning and that learning occurs organically as a natural process that ensues regardless of access to formal schooling (Vygotsky, 1978). According to Vygotsky (1978), learning and development are interrelated concepts that affect each other, but they can also be individually utilized to further the progress of the other. Vygotsky proposed meeting children at their actual developmental level, thereby pushing them past boundaries to stimulate both learning and development (Vygotsky, 1978).

Similarly, modern science standards and engineering practices adopt the same mentality. Modern reliance on critical thinking and problem solving situates students within learning contexts that require them to push beyond their current knowledge and to use it in new, more challenging ways. Armstrong (2015) noted that, when students were paired with more capable peers—as is recommended by Vygotsky and his theorized zone of proximal development—students in a sustainability science course had notably fewer issues with challenging content. Students engaged in Vygotskian social learning practices self-reported a high degree of interest and enthusiasm for the content, while comfortably abandoning misconceptions regarding accurate information (Armstrong, 2015). Therefore, teachers' use of Vygotskian practices, many of which are embedded in the NRC *Framework*, allows students to advance beyond their present levels more comfortably concerning both the acquisition and use of challenging academic content.

Discovery Learning

Discovery learning, another branch of constructivism, is based on the idea that "if man's intellectual excellence is the most his own among his possessions, it is also the case that the most personal of all that he knows is that which he has discovered for himself" (Bruner, 1961, p. 57). That is, knowledge discovered through experience and trial is more valuable than that which was provided. Bruner (2009) suggests that the most valuable learning happens when students are provided with situations that stimulate inquiry and allow them to build on previous knowledge to formulate their own understandings of the world. He was quick to acknowledge, however, that investigations should be authentic and relate to real-world issues that exist outside of the classroom. Bruner (2009) added that the structure and methods utilized by both experts in the field and students in the classroom should be the same. The difference should lie only in the degree of difficulty and the nature of the content confronted by these respective parties (Bruner, 2009).

In the spirit of discovery learning, the modeling of real-world scenarios can be found throughout the NGSS, as students are tasked with analyzing data, constructing models, and using scientific laws to design solutions. Students are asked to apply the content knowledge they have learned in class to authentic learning experiences (Stanford et al., 2018). When children observe and interact with natural phenomena under the appropriate circumstances, their reasoning skills are strengthened (Murphy et al., 2013). However, an activity haphazardly intermixed in a unit does little to foster growth. Students need to immerse themselves in a variety of related experiences over time to receive the full benefit of discovery learning (Hipkins, 2014).

Stanford, Wilson, and Barker (2018) consider the student-directed nature of discovery learning to be a tool which “makes the learning relevant, more meaningful, and memorable” (p. 63). Allowing students to learn informally, they continue, allows “students to develop their level of understanding over time and at their own pace” (Stanford et al., 2018, p. 63). Similarly, Orr (2016), found that limited structure within a discovery-learning context increased students’ ability to make observations and provide evidence for an argument.

Situated Learning Theory

According to the theorists behind the constructivist-based situated learning theory, learning occurs naturally within specific contexts (Brown et al., 1989). Just as a parent would not teach a teenager to drive a car using verbal explanations, reading about cars, and viewing pictures of cars, a teacher cannot adequately engage and prepare students in academic content learning using methods that fail to capture the authenticity and real-world practicality of skills. While these exercises might help with developing the theory and laws associated with driving, the only effective way to learn how to drive is to physically practice driving in a real car, slowly graduating from parking lots to real roads.

In a situated learning environment, learners are expected to make mistakes and to build their skills slowly over time with the guidance of an adult or more capable peer. Similarly, say Brown et al. (1989), students in a classroom should engage in learning within the context of the topic. Students should be afforded the opportunity to use the tools in the way experts in the field do, creating a level of authenticity not available through traditional methods. For example, students learning about botany should care for, observe, and dissect plants using tools similar to those used by botanists. Students studying geologic phenomena should engage in data analysis in a manner that is meaningful and authentic, studying seismographs and analyzing actual rocks and minerals. Through these methods, students gain a deeper understanding of the content by becoming immersed in genuine learning experiences. The social environment is a major factor in the development of learning within the context of situated learning theory (Lave & Wenger, 1991). The student-teacher paradigm is traded for an atmosphere that more accurately represents an apprentice-mentor relationship (Peters-Burton, 2016). The classroom community, much like the scientific community of the real world, becomes imperative to both the sharing of information and the fostering of development (Peters-Burton, 2016).

NGSS and Constructivism

In the spirit of constructivist learning, the NGSS emphasize the active forms of learning over the passive. Students are not situated as receivers of information with the teacher positioned as the provider. Instead, standards are written in such a manner that students are encouraged to develop their own knowledge through immersion in authentic experiences. Learning is dynamic not only when interactions with content, peers, and teachers are valued as valid forms of learning, but also when such interactions serve to mirror the engagement and discourse that takes place within actual scientific communities (Barak, 2017).

According to the researchers Akran and Asiroglu (2018), STEM, at its core, is a constructivist principle in which elements of science, technology, engineering, and mathematics are interwoven using authentic methodologies that relate learning to the experiences that professionals have in the real world. In a manner similar to the key components advocated by the NGSS, constructivist theories of learning involve learning through experiences and connecting concepts to diverse learners through hands-on learning and culturally relevant pedagogy. Constructivist theories also focus on drawing conclusions and making generalizations rather than simply mastering memorized details (Shaw et al., 2012).

Constructivism, in a testament to its hands-on design and generalizability to authentic situations, has been regarded as the pedagogical practice most closely aligned to the needs and demands of the modern world (Cedere et al., 2016). Because it is up to the student to develop interest internally, Cedere, et al. (2016) have suggested the constructivist methodology is appropriate for developing student interest in science, as it relies heavily on the actions and efforts of the student over the actions of the teacher. One researcher reported that students not only showed increased interest in science at school, but at home as well, where their parents reported increased discussion of the topics learned in the constructivist science lessons (Moore-Hart et al., 2002). Additionally, constructivist practices have positive effects on female students (Brown, et al., 2017). Female students are positively impacted by the hands-on experiences and increased freedom that naturally occurs within constructivist learning experiences (Brown et al., 2017).

Related Literature

Many of the issues that permeate the science interest conversation today have existed since the topic first garnered interest in the mid-20th century. Questions surrounding the decline in science interest as students age and the apparent gender differences that exist related to science interest can be traced back to the 1950s and 1960s, when this research began (Weisgerber, 1961).

Researchers have historically found that student interest in science decreases steadily from elementary school to high school. As early as the 1960s, researchers identified a pattern in which students who previously demonstrated talent and interest in the sciences were withdrawing from the discipline by high school (Weisgerber, 1961). As researchers continued to probe, questions and misinformation surrounding the nature of science careers were cited as major reasons for the decline (Weisgerber, 1961). With over 50 years of research and study dedicated to this conundrum, the data continues to confirm these same concerns (Bryant et al., 2013). Although pedagogy has evolved to meet the budding research into student learning and the theoretical developments regarding best practices, decades-old concerns continue to present issues to both practitioners and professionals in the STEM fields.

In addition to the abatement in science interest as the years of schooling progress, the apparent correlation between gender and science interest has been a major topic in science-education research. The first mention of this issue dates to the 1950s, when researchers began to notice the gender biases that existed within the content (Brown, 1954). Although no gender discrepancies related to interest were revealed at this time, disparities in academic success were common (Brown, 1954). The evolving pattern in which boys were consistently scoring higher on science exams was attributed the materials and programs utilized being intrinsically designed to meet the needs and interests of boys, thus failing to appropriately relate to female students (Brown, 1954). This issue of targeting student interest has persisted into the present, and researchers continue to explore methods of closing the gender gap in science careers.

With these issues becoming apparent, interest in improving science education became mainstream in the 1950s, as researchers began to notice a need to develop a scientific mindset in students. At the time, science education was seen less as a means of producing competitive scientists, thinkers, and innovators and more as a method of producing rational, competent citizens (Brown, 1954). Science education and, more specifically, a scientific mindset were seen as necessary components for students to live as citizens in the world (Brown, 1954). Teachers were advised to achieve this ideal through assigning authentic tasks rooted in real-world problems, implementing controlled experiments in which the scientific method could be utilized, and introducing expository texts from a variety of sources (Heiss, 1958). Such methods would ideally yield a generation of citizens who possessed scientific worldviews defined by “curiosity; freedom from bias, prejudice and superstitions; open-mindedness; critical-mindedness; intellectual honesty; belief in cause and effect; and willingness to change beliefs when new evidence is found” (Heiss, 1958, p. 371). Sixty years later, in 2012, similar goals were expressed as a necessity for all students in the NRC’s *A Framework for K-12 Science Education,* which called for science-literate students who possessed a fundamental understanding of scientific processes and the ability to use reason with regard to scientific claims.

In the 1960s, researchers and teachers gravitated away from the focus on developing scientific principles and began to focus on the glaring discrepancy between science aptitude and those entering into science careers. The research of that time produced the first focus on utilizing technology, in the form of films, to determine optimal approaches to increasing student interest in science and improving science-education outcomes. Researchers deduced that specific types of films, namely motivational films, were more successful in increasing student motivation than strictly educational videos (Weisgerber, 1961). However, when these films failed to produce a surge of interest in scientific careers, researchers continued to test and theorize new solutions to this growing problem. Thus, the 1970s ushered in the era of activity-oriented science with more of a focus on science skills and hands-on experiences over text-based methods. Researchers determined that this focus on activities, experiments, and authentic experiences not only increased interest in science, but produced positive attitudes toward school in general (Jaus, 1977).

Newly researched data on students and science in the 1970s brought about a plethora of interest and research in the 1980s. Consistent with previous research, data suggested students were less interested in science careers due to misconceptions surrounding the nature of careers in the science fields and an adherence to ill-informed, stereotypical ideas concerning what scientists were like as people (Kahle & Lakes, 1983). Later research revealed that frequency and comprehensive use of laboratory materials was able to reverse many of these misconceptions and contributed to higher achievement and increased interest toward science (Okebukola & Adeniyi, 1987). The investigation continued into the 1990s, as researchers began to elaborate on previously explored research. This decade saw the first mainstream movement for inquiry-driven lessons in science, building on research from the 1970s and 1980s that supported hands-on laboratory experimentation (Farenga et al., 1998).

The explorations of the 20th century laid the foundation for the work of the 21st century, as researchers, scientists, and teachers banded together to find answers to many of the same questions that have existed since the 1950s. With decades of research supporting the need to increase student interest in science, and a growing reliance on science careers, efforts to determine methods of guiding students toward these fields has only intensified in recent years. Addressing the need, determining the cause of the decline in interest, understanding societal trends, and working to remedy those problems, have therefore been major topics of research related to science education.

A Focus on Science

With experiences in high school diversifying to meet the needs and pique the interests of all students across disciplines, justification as to why a specific focus on science is so critical to modern education is integral to any discussion on science interest. The sciences are not only necessary for understanding the intricacies of the world and its natural phenomena, but also for designing and building the future of medicine, entertainment, manufacturing, communication, and environmental protection. In a global and constantly advancing society, students must be competitive. That competition means students not only need to be proficient in science, but innovative in its use. According to Gokhale et al. (2015), “countries that maintain a competitive edge and prosper will be countries that are most effective in developing their human capital and in nurturing individuals with the capabilities of developing new ideas and innovations, especially in the scientific and technological enterprise” (p. 515).

With human capital a major resource in the science fields, the Western world may be at a slight disadvantage in the coming years. Those in developed, Western nations are more likely to have rigid views of science than their Eastern counterparts, leading to decreased interest and a thinner pool of qualified candidates for science study (Van Griethuijsen et al., 2014; Senler, 2015). This lack of interest, however, does not appear to be related to a general disinterest in

STEM subjects, but directly related to educational and career prospects as students are said to have reported increased enjoyment and interest in science and technology concepts outside of school than they report experiencing within the classroom (Potvin, 2014).

Because students have indicated an enjoyment of science outside of the classroom, it can be deduced that the disconnect between students and science interest occurs within the context of formal science education (Potvin, 2014). Thus, the undertaking of increasing science interest must occur within the schools. Before researchers can study science interest in schools, however, the factors that contribute to the enhancement and deterioration of interest must be clearly understood within the context of the educational setting.

Defining Interest

Much of the research related to science education has focused on developing students' interest in science both inside and outside of the classroom. The focus has remained concentrated on the affective domain, because research has suggested student interest "can play a profoundly important role in students' postschool lives, possibly an even more significant role than that played by students' cognitive achievements" (Popham, 2009, p. 85). Therefore, when striving to produce competitive thinkers and science-literate citizens, the emotions and psychological responses students have toward science while in school is more pertinent to their long-term science interest than their achievement within the classroom.

Interest, however, is not easily defined or studied, given that it encompasses an array of internal and external factors that interact to produce a person's feelings and beliefs. Oshborne et al. (2003) outlined a number of elements that act as variables in the development of a student's interest. Internal factors include the student's perception of the science teacher, their level of anxiety toward science, the value they perceive science has, their self-esteem, motivation, and enjoyment of science, as well as their fear of failure (Oshborne et al., 2003). Factors outside of the student's locus of control include the attitudes of their peers, friends, parents, and close family toward science, and the level of success the student has experienced within the science class (Oshborne et al., 2003). These competing and layered influences are intricately woven together in such a manner that determining the best methods of developing interest can be challenging for researchers and teachers alike. Nevertheless, researchers remain confident that increasing interest in STEM disciplines is vital to expanding the number of highly qualified professionals in the field. The United States Department of Education (2010) reiterated this sentiment, stating:

> The more interested students are in a subject, the more involved they become in their assignments, putting effort into their studies and engaging in deeper levels of thinking. Experts believe that increased student engagement in math and science at school will eventually lead to involvement in math- and science-related afterschool activities and career aspirations. (p. 1)

As researchers have continued to focus on increasing STEM interest through education, barriers and methods for overcoming obstacles have grown increasingly apparent. Through research, experts have identified pedagogical best practices, many of which were utilized in the designing of the NGSS.

Gender Disparities

Recently, the Economics and Statistics Administration, a branch of the U.S. Department of Commerce, commissioned a study to determine the status of women in STEM fields in terms of career paths, degree attainment, and economic outlooks. According to the study, women continue to be disproportionately underrepresented in STEM fields (Noonan, 2017). While women account for an equal proportion of college degrees overall, only 30% of STEM degree holders are women (Noonan, 2017). According the National Science Foundation (2019), the only STEM discipline in which women were awarded an equivalent or greater percentage of degrees compared to male peers was in the field of biology, in which women were awarded the majority of bachelor's, master's, and doctoral degrees. Females' bachelor degrees in engineering rose from 18.4% in 1997 to a modest 20.9% in 2016, while the number of bachelor degrees in physics awarded to women has remained stagnant for 20 years (National Science Foundation, 2019). Other STEM fields have seen a decrease in the percentage of women earning bachelor's degrees over the past 20 years, including computer science at 19%, down from 27%, and mathematics and statistics (once at 46.3%) down to 42.4% in 2016 (National Science Foundation, 2019).

Statistics outlining female participation in STEM continue to descend when women enter the workforce. Presently, women comprise roughly 47% of the total U.S. labor pool and represent only 24% of STEM-related positions (Noonan, 2017). Compared to males with a comparable degree, women with STEM degrees are less likely to work in a STEM field after graduation (National Science Foundation, 2019; Noonan, 2017). Women with STEM degrees are also more likely to work in STEM-related fields, such as health care, or in non-STEM careers (National Science Foundation, 2019). The trend in which fewer women pursue STEM careers serves to harm women financially, as women who work in STEM occupations earn, on average, 35% more than women with comparable qualifications working in non-STEM fields (Noonan, 2017).

The extent to which the absence of women in STEM fields impacts scientific discovery and discourse is unknown, but Gokhale, Rabe-Hemp, Woeste, and Machina (2015) boldly claim, "the focus on reducing gender disparity across all fields of (science and technology) takes on greater urgency as we cannot afford to ignore the potential contributions of half of the nation's population" (p. 515). Albrechsten (2018) argued the value of women in STEM fields lies not only in the diversity within the workplace, but in the diversity of thought and perspective. Women, with their own unique lenses through which they view both the world and its challenges, are able to offer insight into functionality and design that may otherwise be missing (Albrechtsten, 2018). Their representation is therefore crucial to furthering the fields of science and technology (Albrechsten, 2018).

While the full extent of the cause of the underrepresentation of women in STEM is unknown, speculation suggests a variety of factors could be contributing to this national problem including "a lack of female role models, gender stereotyping, and less family-friendly flexibility in the STEM fields" (Beede et al., 2011, p. 1). Of these possibly contributing factors, one of the most documented issues impacting male and female differences in science interest is the prevalence of stereotypes within certain career fields. Public perception, for example, has indicated that traditionally male-dominated fields, such as engineering and physics, require a higher degree of innate ability and greater intelligence compared to historically female-dominated fields (Leslie et al. 2015; Meyer et. al, 2015).

To further exacerbate the above perception, research has revealed that men and women tend to express more interest in careers that have traditionally been populated by their own gender (Tellhed et al., 2017). This phenomenon has a strong influence on middle school students exploring potential careers and establishing the interests that will later predict their career path (Tellhed et al., 2017). Stereotypes of the career choices of men and women based on ability and traditional gender roles become a challenge to combat as they are deeply engrained in the culture (Caliskan et al., 2017). In fact, Godec (2018), found that girls do not outwardly consider gender to be a factor when they consider STEM fields as potential careers. However, data demonstrate that, with STEM in particular, female students have established a markedly lower self-efficacy in the sciences as a result of the persistent stereotypes by middle and high school, thus making them less likely to explore STEM careers (Tellhed et al., 2017).

With research indicating young girls have all but established their career paths well before applying to colleges, attention has been redirected to schools as a vehicle for change. It has become clear that the problem does not exist with educating girls in science, but in piquing their interest and leading them to discover the potential of career aspirations within STEM disciplines (Cunningham et al., 2015). Girls, for example, enroll in an equal or greater proportion of math and science courses as boys in high school (Cunningham et al., 2015). Nevertheless, their pursuit of academic achievement stands in stark contrast to their diminishing interest, which is consistently lower than that of their male peers (Cunningham et al., 2015).

Wang and Degol (2017) suggest female students may be able to be more highly influenced by interest than male students due to the natural, neurological abilities and strengths of women compared to men. Because STEM-minded females tend to have more balanced math and verbal abilities compared to males, who tend to be more mathematically dominant, the balance in their abilities leads many young women to follow their interests as opposed to their strengths (Wang et. al, 2017). Meanwhile, research has indicated a negative correlation between girls' age and their interest in science, which is not apparent with boys (Catsambis, 1995; Cunningham et al., 2015; Kerr, 2016; Shymansky & Kyle, 1988; Simpson & Oliver, 1990; Weinburgh, 1995). Recent research has confirmed the trend of decreasing female interest. Brown et al., 2017) found that male and female interest and participation in STEM are equal in elementary school but steadily diverge as students approach high school graduation. Aptitude is not to blame in this instance, as boys and girls have been found to score comparably on knowledge-based assessments (Leman et al., 2016; Weeden et al., 2020).

While the general aptitude of females versus that of males has not been found to be an indicator of STEM-interest disparity, the strong gender stereotypes that persist within the science fields have led to girls' repeated disassociation of femininity with science careers (Makarova & Herzog, 2015; Lane et al., 2012). For instance, in one study, while two thirds of the young women interviewed were successful in science, earning high marks and participating in science-related clubs and extracurricular activities, less than half of the group considered themselves to be "sciencey" (Godec, 2018). In another study, high-school-aged young women indicated that they believe STEM fields lack creativity (Valenti et al., 2016). Thus, the preconceived notions and female stereotypes are compounded, leading to a decrease in interest as female students age from elementary to high school (Eccles et. al, 1993; George, 2006; Quinn & Lyons, 2011; Simkins et al., 2005; Valenti et. al, 2016). The trend in which female interest decreases over time therefore emphasizes the depth of the persistent disparity between female and male interest and participation in STEM fields.

While the issue of gender participation disparities is multifaceted and evades simple answers and solutions, some methods aligned to the principles of the NGSS have been found to increase student interest. Related to the NGSS, it has been found that girls are more likely to enroll in STEM classes when the classes center on confronting real-world problems (Weber, 2012). In addition, hands-on, project-based, and inquiry-driven learning has been determined to be effective in developing more positive perceptions for girls than for their male peers (Brown et al., 2017). Other factors such as relating science to female interests (Hasni, 2015; Swafford & Anderson, 2020), developing self-efficacy (Phelan et al., 2017; Tellhed et al., 2017), fostering a growth mindset (Vervaeke & Ferraro, 2013), and expanding students' perceptions of STEM (Wyss, 2013) have all been attributed to higher levels of science interest, particularly for female students.

Developing Interest in Science

Through the copious studies investigating barriers to science interest, researchers have developed pedagogical practices and methodologies linked to positive outcomes. Research focused on increasing science interest has elicited a series of themes which reappear continuously. The areas most robustly correlated with increased science interest include experiential teaching strategies, culturally relevant pedagogy, supporting positive self-perceptions, encouraging the development of a growth mindset, and expanding students' understanding of STEM as both a field and a career prospect.

Pedagogical Practices

In general, the pedagogical methods encouraged within the NGSS have been linked to higher interest in science. Traditional methodologies, which rely on teacher demonstrations, rote learning, tasks occupying the lower levels of Bloom's Taxonomy, and lecture-style delivery, have been related to both poorer perceptions of and decreased interest in science (Hacieminoglu, 2015; Odom, 2013). Furthermore, these methods are minimally effective at advancing science-process skills (Odom, 2013). Instead, student-centered teaching methods in which students apply knowledge to solve authentic problems are recommended (Akcay, 2015).

These practical, authentic STEM experiences not only lead to increased interest, but also develop student content knowledge and scientific literacy (Bethke et al., 2013; Farland-Smith & Tiarani, 2016). Authentic scientific experiences help students develop an increase in content knowledge, a robust scientific vocabulary, and their own connections to science concepts

(Djonko-Moore et al., 2018). Bethke, et. al (2013) found that, when embedded in domain-specific science classes, hands-on engineering exercises not only built problem-solving skills, but also lead to an increase in science-content learning. In another study, researchers Farland-Smith and Tiarani (2016) found that students enrolled in STEM courses emerged with a clearer understanding of the diverse and robust practices of engineering than students in traditional science-content courses. Immersive STEM experiences move away from the traditional scientific method and build science, technology, engineering, and math into one cohesive learning experience. Rules and procedures are less focused on controls and formal procedures and, instead, target growth, justification of ideas, revision, and problem solving. This shift from a strictly scientific method of experimentation to an engineering and problem-solving mindset that centers exploration has presented several promising results for researchers concerned with science interest.

With other factors controlled, such as gender and socioeconomic status, teacher lesson delivery and facilitation remain strong predictors of student interest (Hacieminoglu, 2015). While this method of education has been proven to be effective for all students, female students are particularly impacted by both hands-on experiences and the ample freedom within projects that authentic learning experiences often provide (Brown et al., 2017).

Culturally Relevant Pedagogy

While pedagogical practices remain a high predictor of student interest in science, culturally relevant pedagogy that responds to student gender, race, and background also plays a significant role in increasing student interest in STEM domains (Hasni, 2015). Hasni (2015) encourages educators to incorporate culturally relevant science and technology educational practices early in education. Culturally relevant pedagogy is not a new concept, but it has rarely been applied to science and STEM (Dodo Seriki, 2018). Too often, populations of students that are traditionally underrepresented in STEM are assumed to have deficits in knowledge and education, particularly regarding STEM disciplines (Dodo Seriki, 2018). Culturally relevant pedagogy, however, engages all students, not only those who, by societal standards, fit the mold of being traditionally strong in the sciences (Dodo Seriki, 2018).

To address this need, the creators of the NGSS produced the "All Standards, All Students" initiative, which analyzed the standards through the lenses of background, gender, language, and race (NGSS, 2013). The authors established the Diversity and Equity Team which examined the standards for bias and provided resources addressing diversity, equity, and best practices for traditionally underrepresented learners (Okhee et al., 2014, p. 224). Similarly, the NGSS acknowledge the contributions of both men and women of all ethnic backgrounds to the STEM fields (Okhee et al., 2014). The authors of the NGSS recognized that culture and human interactions are vital to scientific exploration. Lemke (2001) reminds science educators that

> cooperative human activity is only possible because we all grow up and live within larger-scale social organizations, or institutions… Our lives within these institutions and their associated communities give us tools for making sense of and to those around us (p. 296).

To understand the tools and cultural influences that led to earlier scientific discoveries, as well as the cultural capital possessed by modern students, the NGSS established culturally relevant pedagogical practices (Okhee et al., 2014). It is recommended that teachers bridge students' cultural experiences and provide students with opportunities to engage with experienced professionals within the STEM field who reflect the experiences of the students (Strachan, 2017; Januszyk et al., 2016).

While some have focused on student gender and race, others have emphasized instruction connecting science to students on a personal level that relates to their interests (Potvin, 2014). Research conducted prior to the implementation of the NGSS found that science content and students' interests were often disconnected (Buxton, 2010; Elmesky & Seiler, 2007). Focusing on the interests of many modern students, web-based learning, and specifically non-biased web and technology-based learning, has been proven to increase student interest in science (Ercan, 2014; Korur et al., 2016). Research, however, has indicated that students often self-report a significantly higher degree of interest in technology outside of school but report lower interest in the same concepts when they are presented within the classroom (Hasni, 2015). Research has also suggested that students are motivated to learn when using methods that mimic the activities with which they readily choose to engage in their everyday lives (Kör et al., 2017). Therefore, researchers and teachers are charged with identifying the potential academic applications of students' use and incorporation of technology outside of school.

Technology has become an ingrained element of American society and people have the ability to constantly update and educate themselves using devices conveniently located in their pockets. Teaching students how to use these tools and providing them with exploration activities that use the tools with which they are most accustomed allows teachers to meet students at their individual interest and readiness levels with content-specific tasks. Within the pedagogical guidelines of the NGSS, the authors emphasize incorporating student interest through methods such as utilizing community resources and incorporating contemporary issues that affect students' daily lives (Strachan, 2017; Januszyk et al., 2016). They also recommend using multimodal teaching methods that incorporate diverse strengths and relate to student interest (Strachan, 2017; Januszyk et al., 2016).

Developing Self-Efficacy

The underlying pedagogical philosophy of the NGSS has led to calls for these standards to be used for all learners as a means of increasing their positive self-perceptions (Aschbacher, 2014). After observing the impact of student self-efficacy on success, Aschbacher (2014) recommends using the NGSS as a starting point for increasing interest by focusing on "doing science" versus learning facts (Aschbacher, 2014). A positive relationship exists between science self-perception and interest; however, the opposite is also true (Phelan et al., 2017). Students who could be described as "underconfident"—meaning their perception of their performance is lower than their actual ability level—display less interest in science than those who hold an accurate impression of their science abilities (Sheldrake, 2016). Thus, students are more likely to have positive attitudes toward science and display increased enjoyment in the subject when they have a high self-perception (Aschbacher, 2014).

By increasing reliance on performance-based assessments, students have a greater degree of control over their performance and achievement in the typical science class. This concept can be applied to all domains and facets of science (Dierks, 2016). Helping students to increase their self-efficacy by developing metacognition and practicing effective learning strategies based on their own needs should begin in elementary school in order to secure the greatest effect on students as they develop (Akilli & Genç, 2017). Research has revealed that students who believe they can tackle a task are more likely to employ the necessary strategies to achieve their goals (Akilli et al., 2017). These skills foster a respect for the field and also an awareness of one's own learning needs. They allow students to improve several of the skills most critical to science success, helping them to develop deeper understandings of previously learned material and to create meaningful, lasting connections to concepts they are only beginning to explore (Akilli, et al. 2017). These results are even more critical to increasing female participation in STEM (Tellhed et al., 2017). Given the negative stereotypes surrounding female students, self-efficacy is "the most important mediator of gender differences in interest in STEM majors" (Tellhed et al., 2017, p. 93).

Fostering a Growth Mindset

Recent research pioneered by Dweck (2000, 2006a) regarding beliefs about innate ability versus the value of effort has helped clarify the phenomena known as mindset. According to Dweck (2000, 2006a), individuals may attribute success to factors on a continuum that ranges from natural ability to individual effort, or from fixed to growth mindsets. Students who exhibit a growth mindset describe attempting challenging tasks to gain new learning, knowledge, skills or simply for the sake of the challenge itself, while those who fall under the category of a fixed mindset are focused on completion, success, competition, or appearance (Blackwell et al., 2007). The percentage of adolescents falling within each of these categories is nearly equivalent. Between 40% and 45% of high school students subscribe to the fixed mindset mentality, with an equal percentage adopting a growth mindset (Dweck, 2000). The remaining 15% of adolescents exist between these two extremes, falling in the middle of the continuum (Dweck, 2000).

Operating under the presumptions of a growth mindset has been shown to have numerous benefits for students and adults alike. For example, students with a growth mindset are more likely to pursue multiple avenues of learning and success in difficult academic courses (Grant & Dweck, 2003). Following failure, these students increase their effort in order to recover, learn from their mistakes, and attain a level of success (Blackwell et. al, 2007). Students with a growth mindset are also more likely to seek challenging opportunities and to persevere through difficult academic tasks (Howell and Schumann, 2009; Dweck, 2010). As a result of their struggle, these students attain deeper learning and attain higher overall achievement than those who operate according to a fixed mindset (Dweck, 2010; Sisk et al., 2018).

Those with a growth mindset not only exhibit similar behavior patterns, but also mirror each other in brain functions. Recent neuroscience research into mindset has demonstrated that students with growth mindsets are more aware of mistakes and have a more positive response to corrective feedback (Moser et al., 2011). Thus, the benefits of a growth mindset, and the corresponding disadvantages of a fixed mindset, are programmed within the brain (Ng, 2018).

More optimistically, whereas mindset certainly plays a major role in student effort and achievement, researchers have found that whether a person has a fixed or growth mindset is not a permanent state. Fixed mindsets can be transitioned to a growth mindset through interventions (Yeager & Dweck, 2012). In one experiment, Grade 9 students' decline in interest and learning was halted, or in some cases reversed, following explicit mindset training (Schmidt et al., 2017). Even brief mindset interventions led to changes in behavior that positively affected student outcomes in just one semester (Haynes et al., 2016).

Mindset and motivation are interrelated concepts (Ng, 2018). Growth mindsets produce higher rates of intrinsic motivation that, in turn, leads to higher levels of interest and exploration (Vervaeke & Ferraro, 2013). This is notably true when examining success in STEM fields in which mindset plays an even more influential role in student interest and achievement (Dweck, 2006b). In relation to science education and increasing student interest, a person's personal belief about the likelihood of their own success has been found to be highly correlated to career interest and attainment (Lauermann et al., 2017). Those with growth mindsets focus less on their own innate intelligence and ability and more on their effort, leading to higher levels of achievement (Sisk et al., 2018).

Expanding Concepts of STEM

Another major factor which inhibits the growth of science-literate and enthusiastic students is the existence of misconceptions surrounding STEM practices, concepts, and careers. This concern has long been documented as a threat to science engagement (Weisgerber, 1961). Over the past several decades, researchers have routinely administered assessments in which participants describe the general aesthetic and disposition of scientists. Consistently, across decades of data and research, students have drawn or described scientists as White, unkempt men working in a stereotypical chemical laboratory (Barman, 1997; Bodzin & Gehringer, 2001; Chambers, 1983; Finson, 2002; Finson et al., 2006; Mason et al., 1991; Turkmen, 2008; Schibeci, 1986). Despite efforts to expand students' notions of STEM practices and professionals, outdated yet pervasive stereotypes have proven difficult to combat. When asked to illustrate scientists and engineers, students as recently as 2016 were more likely to draw male than female figures (Farland & Tiarani, 2016).

The authors of the NGSS, however, acknowledged the issue of narrow, marginalized concepts of STEM and embedded methods and pedagogical practices to help expand student understandings of STEM practices, professionals, and careers. Through the inclusion of SEP and major concepts in the study of the nature of science, one of the chief aims of the NGSS is to generate a deeper understanding of science as a field and scientists as practitioners and people. In part, this stems from the recommendations made within *A Framework for Science Education* developed by the NRC, which explicitly refers to active engagement in science throughout the report (NRC, 2012; Sinatra et al., 2015). The authors specifically recommend practices such as developing questions or problems, creating and using models, planning and conducting investigations, interpreting data, quantifying results, using evidence to justify solutions, and communicating results to help instill an understanding of science as a process and scientists as practitioners (NRC, 2012; Sinatra et. al, 2015).

While research on the effects of a multifaceted STEM education is ongoing, recent research has suggested the inclusion of STEM practices may be beneficial to broadening students' understandings of STEM. In one study, Farland-Smith and Tiarani (2016) found that students enrolled in courses that focused on the multiple components of STEM, as opposed to individual domains, gained a better understanding of the diverse practices of engineering, a major factor in expanding students' perceptions of STEM. This method of explicitly exposing students to the many options that exist within STEM careers can lead to increased interest (Wyss, 2013). It has been noted that, in order for students to accurately understand a career in STEM, it is imperative that they receive accurate information regarding the vast array of careers available in the sciences, and the nature of scientific study as both a career and a valuable aspect of society (DeWitt & Archer, 2015).

Summary

Since the 1960s, researchers have observed a stark decline in interest in science as students progress through school (Bryant et al., 2013; Van Griethuijsen et al., 2014; Weisgerber, 1961). This decline in interest has become problematic, as it ultimately leads to a decreased desire to pursue science careers, thus lowering the overall number of qualified individuals entering the STEM fields (Blalock et al., 2008; Wiebe et. al, 2018). The problem of declining interest, however, starts well before students enter college or the work force, with many researchers turning to elementary, middle school, and high school teaching practices as methods of improving student outcomes (Bryant, et al., 2013; Van Griethuijsen, et al., 2014). Declining interest in STEM has been attributed to an array of problems plaguing 21st century STEM instruction, including content, ineffective teaching practices (Bethke et al., 2013), the perceived difficulty of the content or skills (Murphy & Beggs, 2003), cultural factors, implicit bias (Hasni, 2015), and parental and social influences (Farland et al., 2016). The pedagogical practices outlined in the NGSS, however, are designed to tackle many of these issues.

Fostering a high degree of interest in STEM disciplines through effective science education, and increasing the flow of students into science-related fields, has been an issue of concern for both science and education researchers for decades. Recent research into STEM fields and the existing disparity in gender participation has clarified this problem outside of the school system (Noonan, 2017; Beede et al., 2011). With women entering STEM occupations at approximately one third the rate of men, researchers have questioned the effect of this trend on the continuing progression of the field as a whole, and the effect it may have on scientific discourse and discovery (Noonan, 2017; Gokhale et al., 2015). To address the gender disparity, modern research, building on years of previous research, has shifted to focus on inquiry-driven, hands-on, cross-curricular, STEM-based methods that mimic actual scientific exploration because the research has implied that these methods may increase interest in science (Hacieminoglu, 2015; Odom, 2013; Akcay, 2015; Bethke et al., 2013).

In addition to constructivist teaching and inquiry-based presentation styles, other methods have also been demonstrated to increase student interest in science. Specifically, pedagogical practices that appeal to the child’s sense of self have proven to have positive effects. When students are provided with learning opportunities that allow them to feel successful and develop a sense of self-efficacy, they are more likely to develop higher levels of interest within their chosen discipline (Akilli et al., 2017). As students reflect on learning and activities and come to see their efforts, not their innate intelligence, as the driving force behind their success in the science classroom, student interest grows and career prospects flourish (Sisk et al., 2018). Confidence in their effort is particularly important for students who are traditionally underrepresented in STEM, and who may not be viewed as exhibiting the stereotypical qualities that predispose a person to a career in the sciences (Dodo Seriki, 2018).

Responding to these reoccurring themes within the research, the NGSS presents opportunities to increase constructivist, discovery-based, experiential learning activities, which are designed in such a way that they respond to the diverse experiences of modern students (NGSS, 2013). What is not known, however, is whether the implementation of these standards has impacted the interest of students toward science and whether any potential increase in interest may be significant enough to positively affect the persistent discrepancy between male and female participation in STEM careers. Although Aschbacher (2014) recommends NGSS as a starting point for increasing student interest in science, little research has been conducted to substantiate this recommendation. Aschbacher's (2014) justification for promoting the NGSS was derived from the standards' innate design, the research-based structure, and the focus on "doing science" versus learning facts, a rationale that remains supported by research.

The goal of the present research is to determine whether the NGSS have impacted students' interest in science; particularly male and female students in public schools, using a sample population of Grade 9 and Grade 10 students enrolled in schools in Pennsylvania. Answering the question as to whether the NGSS are effective in increasing student interest in science is particularly necessary for female populations, who continue to be underrepresented. This research therefore focuses on assessing student interest in science in public high schools that have participated in either the NGSS curriculum or in traditional state curricula.

CHAPTER THREE: METHODS

Overview

The NGSS are purported to stimulate students' interest in science and prepare them for college, careers, and citizenship but, to date, no research has validated this claim. Research has, however, suggested that many of the teaching methods recommended by and embedded within the NGSS are beneficial in increasing students' interest in various science domains. For example, real-world problem solving and hands-on activities within STEM classes have been studied and found to have a strong correlation to increased student interest and overall science affect (Hacieminoglu, 2015; Akcay, 2015; Odom, 2013; Erdogan & Stuessy, 2015). The design of this study aims to determine the validity of the claims of the NGSS in relation to students enrolled in Grade 9 and Grade 10 general science courses in public high schools. The sample population is students enrolled in school districts in Pennsylvania. This study also investigates whether the NGSS affects the disparities in STEM interest between male and female students.

Design

A causal-comparative research design was implemented to determine whether a relationship exists between the independent variables (science standards and participant genders) and the dependent variables (interest toward science, technology, engineering, mathematics, and overall interest in STEM). Causal-comparative research refers to nonexperimental studies in which the independent variables are not manipulated by the researcher to determine whether groups differ on the dependent variable (Gall et al., 2007). The causal-comparative design utilizes nominal groups for the independent variables, in this case, NGSS or non-NGSS standards and gender, and intervals for the dependent variables of interest in science, technology, engineering, mathematics, and overall STEM interest (Gall et al., 2007). The American

Psychological Association defines interest as "an attitude characterized by a need or desire to give selective attention to something that is significant to the individual, such as an activity, goal, or research area" (APA Dictionary of Psychology). Researchers have identified various internal and external variables that influence a student's interest, including degrees of anxiety, value assigned to the topic, self-esteem, motivation, enjoyment, fear of failure in science, and the opinions of those around them (Oshborne et al., 2003). In this study, interest was quantified by the researchers through a combination of questions involving the self-reporting of self-efficacy, personal goals, outcome expectations, and contextual support (Kier et al., 2014). The survey items include both internal and external factors that influence a student's interest in the individual fields of science, technology, engineering, mathematics, and STEM overall.

Research Question

The research question for this study is as follows:

RQ: Is there a difference between students' interest scores in science, technology, engineering, mathematics and overall interest in STEM, as measured by the STEM-CIS, when enrolled in schools that have adopted NGSS as compared to those enrolled in schools that have not adopted NGSS based on the gender of the student?

Hypotheses

The hypotheses for this study are as follows:

$H_0$1: There is no statistically significant difference between students' interest scores in science, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not adopted the NGSS.

$H_0$2: There is no statistically significant difference between students' interest scores in technology, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not adopted the NGSS.

$H_0$3: There is no statistically significant difference between students' interest scores in engineering, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not adopted the NGSS.

$H_0$4: There is no statistically significant difference between students' interest scores in mathematics, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not adopted the NGSS.

$H_0$5: There is no statistically significant difference between students' interest scores in overall STEM, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not adopted the NGSS.

$H_0$6: There is no statistically significant difference between male and female students' interest scores in science, technology, engineering, mathematics, and overall STEM, as measured by the STEM-CIS.

$H_0$7: There is no statistically significant difference between male and female students' interest scores in science, technology, engineering, mathematics, and overall STEM, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not adopted the NGSS.

Participants and Setting

Participants for the study were selected from two public high schools in Pennsylvania. Pennsylvania is one of the states that has adopted neither the NGSS nor an updated set of standards based on the NRC's 2012 *Framework* (National Science Teachers Association, 2019).

The Pennsylvania science standards were planned throughout the 1990s and officially adopted in 2002 (Remington, 2018). Critics are quick to point out that monumental scientific feats have occurred since the birth of the Pennsylvania science standards, including the introduction of the iPhone, the landing of the Mars Rover, and even the widespread availability of the internet (Murphy, 2019; Remington, 2018). Two high schools that are implementing the traditional Pennsylvania standards were randomly chosen from suburban Pennsylvania towns. Next, matching techniques were used to select comparable high schools within suburban areas of Pennsylvania that have adopted the NGSS. Data for matching was collected via the 2016 census data. All the classes of Grade 9 and Grade 10 students enrolled in science were offered the opportunity to participate in the survey and to comprise the sample population. The sample population consisted of $N = 294$ participants, 133 males and 161 females. Assuming a medium effect size, 48-62 participants were recommended per group (Stevens, 1992). The number of participants exceeds the required minimum for multivariate analysis of variance (MANOVA) with four groups when assuming a medium effect size with a statistical power of .7 and an alpha level, $\alpha = .05$, and a medium effect size (Gall et al., 2007). Of the sample population, 85.7% was Caucasian, 1% African American, 0.7% Hispanic, 2.7% Asian, 1.7% Native American, and 8.1% of respondents identifying as two or more races. The students in the sample population ranged in age from 14-17 with a median age of 15. Participant demographic information for each of the two groups can be found in Table 1.

Table 1

Participant Demographics

	Participant Demographics	
	NGSS	Non-NGSS
Gender		
Male	79	54
Female	95	66
Race		
Caucasian	81.6%	90.8%
African American	1.7%	0.0%
Hispanic	0.5%	0.8%
Asian	4.0%	0.8%
Native American	1.7%	1.6%
Two or More	9.7%	5.8%
Average Household Income	$83,334	$64,183
Percentage of Low-Income Families	29%	47%

Instrumentation

The STEM Career Interest Survey (STEM-CIS; Kier, Blanchard, Osborne, & Albert, 2014) was used to collect data on the interests of the participants in science, technology, engineering, math, and STEM overall (see Appendix A for permission to use the instrument). The purpose of this instrument is to measure the participants' interest toward each individual aspect of STEM: science, technology, engineering, and mathematics (Kier et al., 2014). The STEM-CIS "measures self-efficacy, outcome expectations, personal inputs, and contextual supports and barriers as predictors of STEM career" in students via self-report measures

(Peterman, Kermish-Allen, Knezek, Christensen, & Tyler-Wood, 2016, p. 834). The STEM-CIS has been widely used in education research to determine middle and high school students' interest in STEM careers in relation to a variety of factors, including science-process skills (Zorlu & Zorlu, 2017) and STEM curricular programming (Talafian et al., 2019). Moreover, the STEM-CIS has been translated into several different languages and has been used around the world to conduct research in countries that include Turkey (Koyunlu Unlu et al. 2016), China (Mau et al., 2019), Malaysia (Shahali et al., 2017), and Korea (Han, 2017).

The instrument was created by a team of researchers for the STEM Career Awareness Project, which sought to implement STEM career education in classrooms serving rural, high-poverty, and minority-majority school districts (Kier et al., 2014). The STEM-CIS was created, piloted, and validated to determine the effects of the STEM Career Awareness Project interventions (Kier et al., 2014). Beginning with a literature review and the development of a theoretical framework, the researchers compiled potential questions. An initial 30-item Likert-style instrument was created and reviewed by experts for validity (Kier et al., 2014). The instrument was piloted with 61 students and items demonstrating poor correlations and low alphas were removed (Kier et al., 2014). The items were reformatted for clarity and piloted with a new group of students (Kier et al., 2014). Following a third round of revisions, the instrument was again piloted (Kier et al, 2014). This third round resulted in the finalized version of the STEM-CIS. The psychometric properties of each individual subscale were tested using a factor analysis (Kier et al., 2014).

The STEM-CIS is a quantitative interest assessment consisting of 44 5-point Likert-scale items in which participants self-report their feelings toward components of STEM career interest, education, and overall enjoyment of STEM. The instrument, which takes approximately 10 minutes to administer (Kier et al., 2014), is divided into four subscales: science, technology, engineering, and mathematics. Each subscale is composed of 11 statements, such as “I am able to get a good grade in my science class,” “If I do well in mathematics classes, it will help me in my future career,” and “My parents would like it if I choose an engineering career.” Each statement includes possible answers 1 – strongly disagree, 2 – disagree, 3 – neither agree nor disagree, 4 – agree, and 5 – strongly agree. To score the tests, results are totaled by the researcher, producing a scoring range of 11-55 for each subscale. Higher scores indicate a higher interest in science. An average is calculated for the test as a whole, with a score of 11-20 indicating low interest in STEM, a score of 45-55 indicating high interest in STEM, and 55 indicating the highest score.

Reliability and Validity

In its development, the STEM Career Interest Survey was administered to over 1,000 middle school students (Kier et al., 2014). The participants selected for initial reliability and the assessment of psychometric properties were primarily enrolled in rural middle schools characterized by a high poverty rate (Kier et al., 2014). The items were developed by a team of researchers with experience in STEM education and were reviewed for validity by being “reviewed by three science educators, one faculty member in educational psychology, and a faculty member in counselor education with expertise in STEM career counseling” (Kier et al., 2014, p. 468). The reported Cronbach’s alpha for each subscale ranges from .77 to .89 (Kier et al., 2014). Since its creation, the STEM-CIS has been demonstrated to be reliable for other populations around the world (Hyesook, 2017; Koyunlu Unlu, et al., 2016; Shahali, et al., 2017; Talafian, et al., 2019; Zorlu & Zorlu, 2017). The instrument has been made widely available to researchers through its publication in the article outlining the development process. A statement from the author authorizing use has also been provided (see Appendix A).

The instrument was administered to the students digitally via Google Forms, allowing students to take the survey on a Chromebook, cell phone, tablet, or computer. On the day of instrument administration, the teachers reviewed the instructions and expectations and modeled a sample item with students by following the script provided by the researcher (see Appendix E for administration guidelines and Appendix F for script). As students completed the survey, the results were sent to the researcher digitally.

Procedures

Prior to beginning the study, the research was reviewed and approved by the Liberty University Institutional Review Board (IRB) to address any potential ethical issues or unintended consequences associated with the design and nature of the study (see Appendix H for IRB approval letter). Following IRB approval, two school districts in Pennsylvania that implemented the NGSS standards were selected (see Appendix B for the letter to participating schools). Next, matching techniques were used to identify similar schools in Pennsylvania that had not implemented the NGSS standards but chose to utilize the traditional Pennsylvania state standards. The NGSS and non-NGSS schools were matched based on the following criteria: geographic location, median household income, percentage of persons below the poverty line, educational attainment of adults in the community, and race and ethnicity. The schools selected resided in similar geographic areas. All data utilized during the matching procedures were accrued from census data taken during the 2016 data collection cycle.

Following approval and agreement from superintendents and principals, teachers instructing Grade 9 and Grade 10 general science classes were informed of the research. Of the interested teachers, four general science classrooms were chosen from each participating school. Parents of the students in the selected classes were contacted and provided written notice and consent letters in the form of an opt-out agreement (see Appendix C for parental consent letter and Appendix G for family recruitment letter). Students were informed that their participation in the study would in no way affect their grade in current or subsequent classes. Students had the opportunity to agree to participate in the study in the form of an assent form located within the digitally administered instrument (see Appendix D for assent form).

The instrument was transcribed into a digital format (Google Forms) for ease of teacher administration. Each school received a unique but identical version of the form, which removed the necessity of student self-selection of schools and maintained confidentiality between the schools selected for the study. The first page of the form requested students provide their gender, race, and age but refrained from collecting other identifiable information, such as names.

Two weeks prior to administration, teachers received a one-page instruction sheet outlining the administration protocol (see Appendix E for administration guidelines). Teachers reviewed the document and had the opportunity to present any concerns or questions to the researcher. The researcher contacted each teacher either via phone or email prior to administration to address any lingering questions.

On the administration day, each teacher began by reviewing the instructions and expectations with students by reading the script provided by the researcher (see Appendix F for script). The teacher modeled a practice item for the students in each group, following a script provided by the researcher. Students were given an opportunity to ask the teacher questions about how to complete the survey. The students took the survey on their devices (phone, computer, Chromebook, tablet, etc.). Devices employed for the use of the study varied across classes contingent upon the individual policies of each school and the availability of devices. Upon each student's conclusion of the survey, the results were sent digitally to the researcher.

Data Analysis

To analyze the data, a between-subjects, two-way MANOVA was utilized. The two-way MANOVA was employed to determine whether the groups differ regarding the five dependent variables (interest in science, technology, engineering, mathematics, and overall STEM interest) and the independent variables (NGSS adoption and student gender; Gall et al., 2007). The two-way MANOVA compared the mean scores for interest in science, technology, engineering, mathematics, and overall STEM interest and tested the main effect of gender, the main effect of the type of standard used in the schools, and the interaction of gender and standard type on student interest scores. Use of the two-way MANOVA allowed for the data to be analyzed in relation to the interaction between the independent and the dependent variables. Each independent variable had two levels. Gender was identified as either male or female, and standard type was reported as either NGSS or non-NGSS.

For the two-way MANOVA, the independent variables were gender and standard type with the following groups (k): females in NGSS classes (n = 95), males in NGSS classes (n = 79), females in non-NGSS classes (n = 66), and males in non-NGSS classes (n = 54). With k = 4, α = .05, and a medium effect size, a n of 48-62 is recommended (Stevens, 1992). The dependent variables were the total score on the STEM-CIS, as well as the individual subscales: interest in science, technology, engineering, mathematics.

Assumption tests were conducted prior to conducting the two-way MANOVA. First, outliers were identified for each group using a Box and Whisker plot. Extreme outliers were evaluated to determine whether they should be removed from the data set. Next, the two-way MANOVA assumed normal distribution (Warner, 2013). Because n > 50, the Kolmogorov-Smirnov test for normality was conducted to verify the assumption. Next, linearity of dependent variables was determined by creating and analyzing a matrix of scatter plots (Warner, 2013). Following the testing for linearity, the Box's M test for the homogeneity of variances was conducted. The Box's M test detects violations across the sum of cross products for each group by creating an *F* statistic (Warner, 2013). A *p* value greater than .05 indicates the assumption is tenable. A separate Levene's test was completed for each dependent variable if the Box's M result was not tenable. Similar to Box's M, Levene's test calls for a *p* value greater than .05 to assume homogeneity of variances. An assessment of the absence of multicollinearity was also conducted to determine the strength of the correlation between the dependent variables (Warner, 2013). A value near to 0 indicates strong multicollinearity, meaning the independent variables are not highly correlated (Warner, 2013). Values over .9, however, indicate that the independent variables, in essence, explain the same variance (Warner, 2013).

Once the assumptions were deemed tenable, the two-way MANOVA was run to determine whether there were statistically significant two-way interactions between the independent variables on the dependent variables. Furthermore, the MANOVA determined whether there were statistically significantly main effects. In conducting the two-way MANOVA, the sample size, *N*, degrees of freedom, *df*, and the number of participants for each group, *n*, were reported along with the mean, *M*, and the standard deviation, *SD*, for each group (Gall et al., 2007). The *p* value*,* or significance, was reported to determine whether it was reasonable to reject the null hypothesis (Warner, 2013). A value of $p < .05$ warranted the rejection of the null hypothesis if all assumptions were met (Warner, 2013). An *F* ratio was also reported. If the *F* ratio was greater than the critical value of *F,* it could be concluded that the independent variable and the dependent variable were predictive (Warner, 2013). The η^2 was used to determine effect size (Warner, 2013). The η^2 indicated the likelihood of group membership to one of the independent variables predicting the outcome for the dependent variable (Warner, 2013). Finally, a Wilks' Λ was examined for a statistically significant difference between the dependent variables: interest toward science, technology, engineering, mathematics, and overall STEM interest.

CHAPTER FOUR: FINDINGS

Overview

The present study seeks to determine whether the type of science standards utilized by school districts impacts the students' interests in STEM. A sample population of 295 students from four high schools in Pennsylvania participated in a survey in which they self-reported their interest in STEM disciplines. Of the sample population, there were 95 females and 79 males enrolled in schools utilizing the NGSS and 66 females and 54 males enrolled in schools utilizing the traditional Pennsylvania standards.

Research Question

RQ1: Is there a difference between students' interest scores in science, technology, engineering, mathematics and overall interest in STEM, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not adopted the NGSS based on the gender of the student?

Null Hypotheses

$H_0$1: There is no statistically significant difference between students' interest scores in science, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not adopted the NGSS.

$H_0$2: There is no statistically significant difference between students' interest scores in technology, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not adopted the NGSS.

$H_0$3: There is no statistically significant difference between students' interest scores in engineering, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not adopted the NGSS.

$H_0$4: There is no statistically significant difference between students' interest scores in mathematics, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not adopted the NGSS.

$H_0$5: There is no statistically significant difference between students' interest scores in overall STEM, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not adopted the NGSS.

$H_0$6: There is no statistically significant difference between male and female students' interest scores in science, technology, engineering, mathematics, and overall STEM, as measured by the STEM-CIS.

$H_0$7: There is no statistically significant difference between male and female students' interest scores in science, technology, engineering, mathematics, and overall STEM, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not adopted the NGSS.

Descriptive Statistics

A two-way MANOVA was performed on the data set using the STEM-CIS subscales (science, technology, engineering, mathematics, and total STEM-CIS score) as the dependent variables. The independent variables were gender (male or female) and standard type (NGSS or non-NGSS), creating a sample size of $N = 294$ with $df = 293$ and the following $k = 4$ groups: females in NGSS classes ($n = 95$), males in NGSS classes ($n = 79$), females in non-NGSS classes ($n = 66$), and males in non-NGSS classes ($n = 54$). The Cronbach's alpha value was 0.82

Results

A two-way MANOVA was used to determine whether the groups (k) differ on the five dependent variables (interest in science, technology, engineering, mathematics, and overall

STEM interest) and for the independent variables (NGSS adoption and student gender), as measured by the STEM-CIS (Gall, Gall, & Borg, 2007). The two-way MANOVA compared the mean scores for interest in science, interest in technology, interest in engineering, interest in mathematics, and overall STEM interest and tested the main effect of gender, the main effect of the standard type used in the schools, as well as the interaction of gender and standard type on student interest scores. Use of the two-way MANOVA allowed for the data to be analyzed regarding interaction between the independent and the dependent variables. Each independent variable had two levels. Gender was reported as either male or female and standard type was noted as either NGSS or non-NGSS.

Assumption Tests

Prior to testing for normality, the data was visually screened for missing data points and analyzed for outliers using a Box and Whisker plot. One outlier was identified, and it appeared when data was analyzed through the lenses of standard type and gender. The outlier was removed from the data set.

Figure 1

Box and Whisker by Standard Type

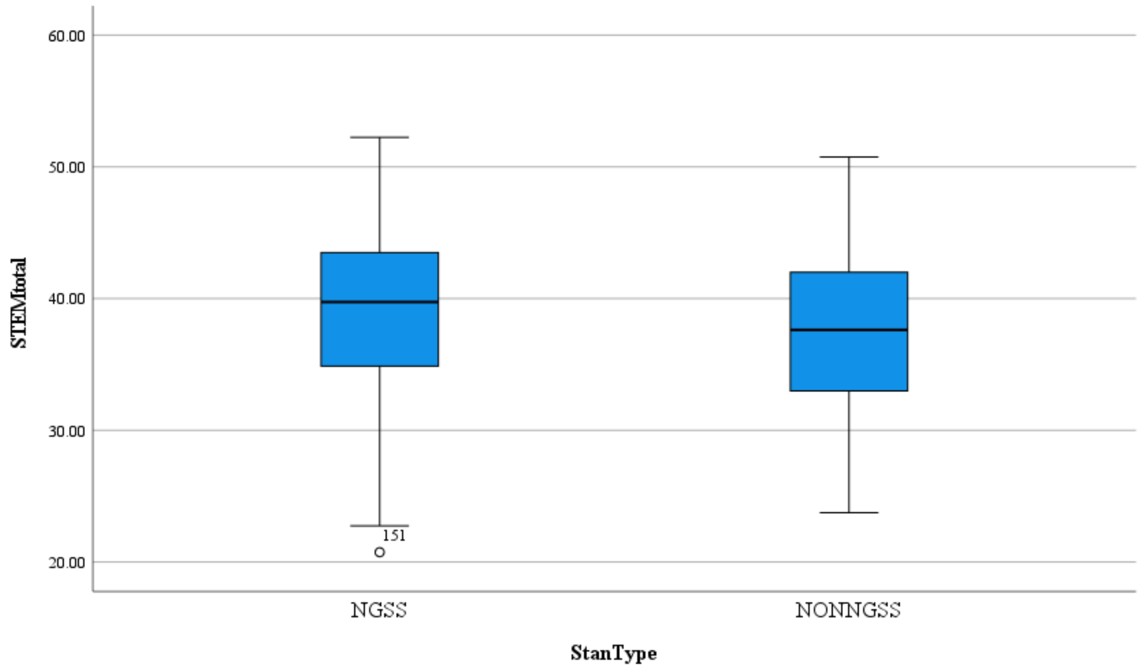
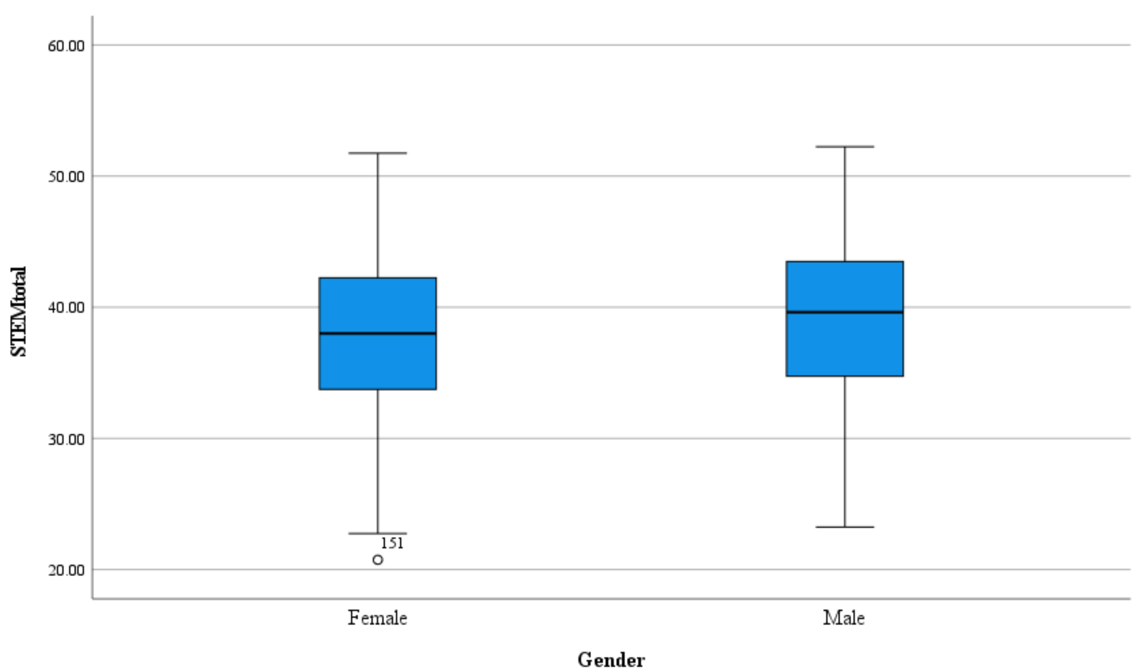


Figure 2

Box and Whisker by Gender



Preliminary data screening was conducted to test for multivariate normality and linearity of associations between quantitative outcome variables. Because the sample population was more than 50 ($n > 50$), the Kolmogorov-Smirnov test (Gall, Gall, & Borg, 2007) was conducted (Table 2) along with a matrix of scatter plots (Figure 1). No violations were found regarding the overall STEM interest score, with $p = .200$ for students in the NGSS classes and $p = .200$ for those in non-NGSS classes. However, the technology and math subscales for the NGSS group failed to meet the assumption of normal distribution, with $p < .001$ and $p = .003$ respectively. The decision was made to proceed with the analysis because an inspection of the histograms for both math and technology indicated that they were each only slightly non-normal, as can be seen in Figures 3 and 4. Warner (2013) recommends the use of histograms to ensure the data set is “reasonably normally distributed” (p. 785).

Table 2

Test of Normality

	Kolmogorov-Smirnov[a]			
	Standard Type	Statistic	*df*	Significance
Overall STEM	NGSS	.05	173	.200*
	Non-NGSS	.05	120	.200*
Science	NGSS	.06	173	.200*
	Non-NGSS	.08	120	.084
Technology	NGSS	.09	173	<.001
	Non-NGSS	.05	120	.200*
Engineering	NGSS	.05	173	.200*
	Non-NGSS	.07	120	.200*
Math	NGSS	.09	173	.003
	Non-NGSS	.07	120	.192

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Figure 3

Technology Histogram

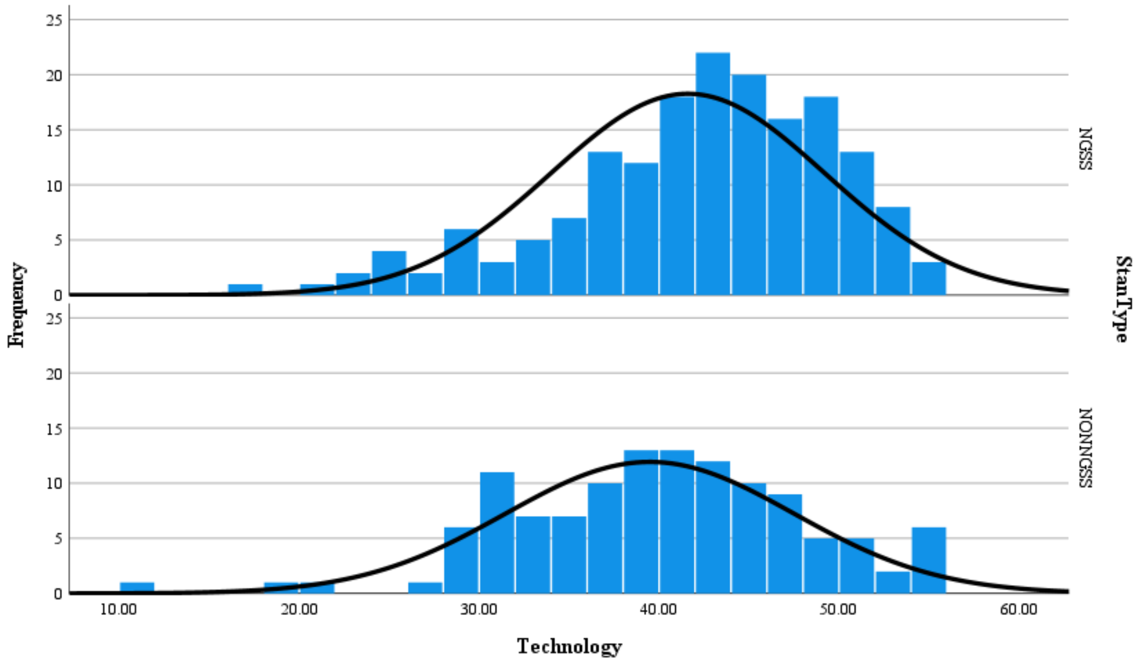


Figure 4

Mathematics Histogram

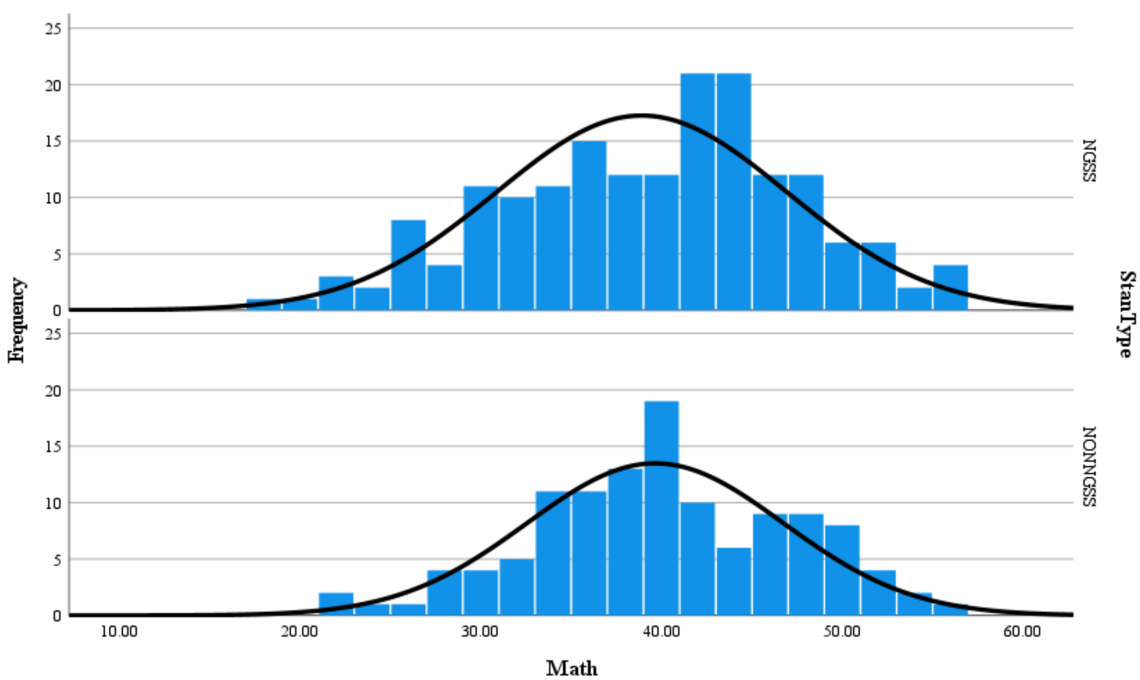
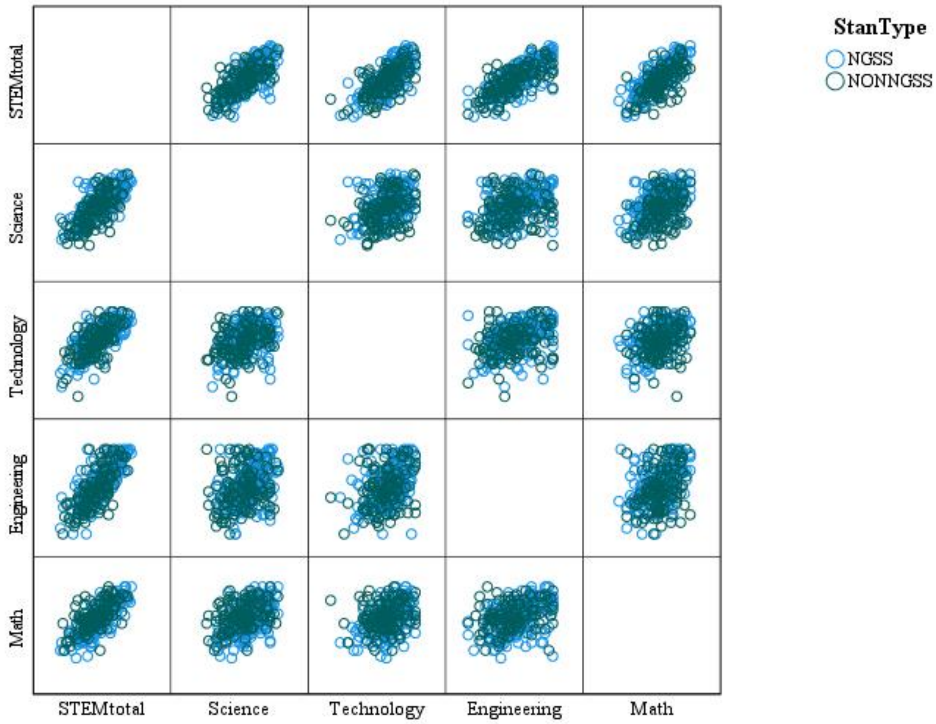


Figure 5

Scatter Plot Matrix



The Box's M test for homogeneity of variances was conducted and the assumption was not tenable (Table 3) with $p = .006$.

Table 3

Box's M Test for the Homogeneity of Covariances

Box's M		25.14
F	Approx.	2.48
	df1	10
	df2	307333.99
	Significance	.006

In addition, a separate Levene's Test for Homogeneity of Variances was conducted for each subscale to test for the assumption of equal variances (see Table 4; Warner, 2013). The significance was $p = .512$ for the overall STEM score, demonstrating that the assumption was tenable. The assumption was also deemed tenable for all subscales ($p = .174$ for science, $p = .406$ for technology, $p = .763$ for engineering, and $p = .052$ for math).

Table 4

Levene's Test for the Homogeneity of Variances

	F	*df1*	*df2*	Significance
Overall STEM	.43	1	291	.512
Science	1.86	1	291	.174
Technology	.69	1	291	.406
Engineering	.09	1	291	.763
Math	3.82	1	291	.052

Null Hypothesis 1

To address the first null hypothesis, a MANOVA was conducted for the sample population $N = 293$ and the $k = 2$ groups in NGSS classes ($n = 173$) and students in non-NGSS classes ($n = 120$). Descriptive statistics for the science subscale can be found in Table 4. The mean score for the science subscale for the NGSS group was $M = 39.861$, with a standard deviation of $SD = 7.4$. Students enrolled in non-NGSS classes demonstrated a mean score of $M =$ 36.5 on the science subscale, with a standard deviation of $SD = 8.5$. The confidence interval was set to 95%, with a lower limit of 38.5 and an upper limit of 44.4.

Table 5

Descriptive Statistics for the NGSS and Non-NGSS Groups – Science

	Standard Type	*M*	*SD*	*N*
Science	NGSS	39.9	7.4	173
	Non-NGSS	36.5	8.5	120
	Total	38.5	8.0	293

The results of the MANOVA were statistically significant, $F(293) = 15.00$, $p < .001$, $\eta^2 = .05$, observed power = .97 (Table 6). The null hypothesis was rejected. The results demonstrate that a difference in science interest exists between students in the sample population who attended schools implementing the NGSS and students in the sample population who attended schools that used traditional Pennsylvania science standards. The descriptive statistics indicate that students in NGSS schools had higher interest toward science than students enrolled in non-NGSS schools.

Table 6

MANOVA Results for the Science Subscale

Tests of between-subjects effects				
	Dependent Variable	*F*	Significance	Partial Eta Squared
Standard Type	Science	15.00	<.001	.05

A partial eta squared was used to determine the effect size of $\eta^2 = .05$, a medium effect size (Warner, 2013). This effect size indicates a relationship between science standard type and student interest in science, with approximately 5% of the variance in interest predictable by the science standard type in this study (Warner, 2013).

Null Hypothesis 2

A MANOVA was conducted to evaluate the second null hypothesis for the sample population $N = 293$ and the $k = 2$ groups in NGSS classes ($n = 173$) and students in non-NGSS classes ($n = 120$). The mean score for the technology subscale for the NGSS group was $M = 41.6$, with a standard deviation of $SD = 7.6$ (Table 7). Students in the non-NGSS group demonstrated a mean score of $M = 39.5$ on the technology subscale, with a standard deviation of $SD = 8.0$. The confidence interval was set to 95%, with a lower limit of 33.4 and an upper limit of 39.3.

Table 7

Descriptive Statistics for the NGSS and Non-NGSS Groups – Technology

	Standard Type	*M*	*SD*	*N*
Technology	NGSS	41.6	7.6	173
	Non-NGSS	39.5	8.0	120
	Total	40.7	7.8	293

The results of the MANOVA were statistically significant, $F(293) = 5.64$, $p = .018$, $\eta^2 = .02$, observed power = .66 (Table 8; Warner, 2013). The null hypothesis was rejected. The results demonstrate that a difference in technology interest exists between students in the sample population who attended schools implementing the NGSS and students in the sample population who attended schools that used traditional Pennsylvania science standards. The descriptive statistics indicate that students in NGSS schools had higher interest toward technology than students enrolled in non-NGSS schools.

Table 8

MANOVA Results for the Technology Subscale

Tests of between-subjects effects				
	Dependent Variable	*F*	Significance	Partial Eta Squared
Standard Type	Technology	5.64	.018	.02

A partial eta squared was used to determine the effect size of $\eta^2 = .02$, a small to medium effect size (Table 8; Warner, 2013). This effect size indicates a relationship between science standard type and student interest in technology, with approximately 2% of the variance in interest predictable by the science standard type in this study (Warner, 2013).

Null Hypothesis 3

MANOVA was conducted for the sample population $N = 293$ and the $k = 2$ groups in NGSS classes ($n = 173$) and students in non-NGSS classes ($n = 120$) to address the third null hypothesis. Descriptive statistics for the engineering subscale can be found in Table 9. The mean score for the engineering subscale for the NGSS group was $M = 36.7$ out of a possible 55, with a standard deviation of $SD = 9.7$. Students enrolled in non-NGSS classes demonstrated a mean score of $M = 34.3$ on the science subscale, with a standard deviation of $SD = 10.4$. The confidence interval was set to 95%, with a lower limit of 23.3 and an upper limit of 30.7.

Table 9

Descriptive Statistics for the NGSS and Non-NGSS Groups – Engineering

	Standard Type	*M*	*SD*	*N*
Engineering	NGSS	36.7	9.7	173
	Non-NGSS	34.3	10.4	120
	Total	35.7	10.1	293

The results of the MANOVA were statistically significant, $F(293) = 3.8$, $p = .051$, $\eta^2 = .01$, observed power = .50 (Table 10; Warner, 2013). The null hypothesis was not rejected. The results demonstrate that a difference in engineering interest does not exist between students in the sample population who attended schools implementing the NGSS and students in the sample population who attended schools that used traditional Pennsylvania science standards. The descriptive statistics indicate that students in NGSS schools had similar interest toward engineering compared to students enrolled in non-NGSS schools.

Table 10

MANOVA Results for the Engineering Subscale

Tests of between-subjects effects				
	Dependent Variable	*F*	Significance	Partial Eta Squared
Standard Type	Engineering	3.84	.051	.01

Null Hypothesis 4

To address the fourth null hypothesis, a MANOVA was conducted for the sample population $N = 293$ and the $k = 2$ groups in NGSS classes ($n = 173$) and students in non-NGSS classes ($n = 120$). Data for the mathematics subscale can be found in Table 11. The mean score for the mathematics subscale for the NGSS group was $M = 38.9$ out of a possible 55, with a standard deviation of $SD = 8.0$. Students enrolled in non-NGSS classes demonstrated a mean score of $M = 39.7$ on the mathematics subscale, with a standard deviation of $SD = 7.1$. The confidence interval was set to 95%, with a lower limit of 37.3 and an upper limit of 43.2.

Table 11

Descriptive Statistics for the NGSS and Non-NGSS Groups – Mathematics

	Standard Type	*M*	*SD*	*N*
Math	NGSS	39.9	8.0	173
	Non-NGSS	39.7	7.1	120
	Total	39.2	7.7	293

The results of the MANOVA were not statistically significant, $F(293) = .44$, $p = .509$, $\eta^2 = .00$, observed power = .10 (Table 12; Warner, 2013). The null hypothesis was not rejected. The results demonstrate that a difference in mathematics interest does not exist between students in the sample population who attended schools implementing the NGSS and students in the sample population who attended schools that used traditional Pennsylvania science standards. The descriptive statistics indicate that students in NGSS schools had similar interest toward mathematics compared to students enrolled in non-NGSS schools.

Table 12

MANOVA Results for the Mathematics Subscale

Tests of between-subjects effects				
	Dependent Variable	*F*	Significance	Partial Eta Squared
Standard Type	Math	0.44	.509	.00

Null Hypothesis 5

A MANOVA was conducted for the sample population $N = 293$ and the $k = 2$ groups in NGSS classes ($n = 173$) and students in non-NGSS classes ($n = 120$). Data for the average score on the STEM-CIS can be found in Table 13. The mean score for the STEM-CIS for the NGSS group was $M = 39.3$ out of a possible 55, with a standard deviation of $SD = 6.2$. Students enrolled in non-NGSS classes demonstrated a mean score of $M = 37.5$ on the STEM-CIS, with a standard deviation of $SD = 5.8$. The confidence interval was set to 95%, with a lower limit of 34.0 and an upper limit of 38.5 for the NGSS group.

Table 13

Descriptive Statistics for the NGSS and Non-NGSS Groups – Overall STEM

	Standard Type	*M*	*SD*	*N*
Overall STEM	NGSS	39.3	6.2	173
	Non-NGSS	37.5	5.8	120
	Total	38.5	6.1	293

The results of the MANOVA were statistically significant, $F(293) = 6.6$, $p = .011$, $\eta^2 = .02$, observed power = .72 (Table 14; Warner, 2013). The null hypothesis was rejected. The results demonstrate that a difference in STEM interest exists between students in the sample population who attended schools implementing the NGSS and students in the sample population who attended schools that used traditional Pennsylvania science standards. The descriptive statistics indicate that students in NGSS schools had higher interest toward STEM overall than students enrolled in non-NGSS schools.

Table 14

MANOVA Results for the NGSS and Non-NGSS Groups on the STEM-CIS

Tests of between-subjects effects				
	Dependent Variable	*F*	Significance	Partial Eta Squared
Standard Type	Overall STEM	6.56	.011	.02

A partial eta squared was used to determine the effect size of $\eta^2 = .02$, a small to medium effect size (Table 14; Warner, 2013). This effect size indicates a relationship between science standard type and student interest in STEM, with approximately 2% of the variance in interest predictable by the science standard type in this study (Warner, 2013).

Null Hypothesis 6

The data for overall STEM interest by gender, as reported by the average total score on the STEM-CIS, can be found in Table 14. Females ($n = 160$) had a mean score of $M = 38.1$, with a standard deviation of $SD = 5.9$ and males ($n = 133$) had a mean score of $M = 39.0$, with a standard deviation of *SD* = 6.3. The confidence interval was set at 95% and produced a lower limit of 39.3 and an upper limit of 43.8 (Warner, 2013).

Table 15

Descriptive Statistics for Female and Male students on STEM-CIS

	Standard Type	*M*	*SD*	*N*
Overall STEM				
	Females	38.1	5.9	160
	Males	39.0	6.3	133
	Total	38.5	6.1	293

The results of the MANOVA were not statistically significant, $F(293) = 3.85$, $p = .305$, $\eta^2 = .00$, observed power = .18 (Table 16; Warner, 2013). The null hypothesis was not rejected. The results demonstrate that a difference in STEM interest does not exist between male and female students in the sample population. The descriptive statistics indicate that female students had a similar interest toward STEM compared to male students.

Table 16

MANOVA Results for Gender Groups

Tests of Between-Subjects Effects				
	Dependent Variable	*F*	Significance	Partial Eta Squared
Gender	Overall STEM	1.06	.305	.00

Null Hypothesis 7

The data for overall STEM interest as reported by the average total score on the STEM-CIS can be found in Table 17. On average, students enrolled in school districts with NGSS implementation (n = 173) had a mean score of M = 39.3 for the total STEM-CIS score out of a possible 55, with a standard deviation of SD = 6.2. Females in NGSS classes (n = 94) had a mean score of M = 38.7, with a standard deviation of SD = 5.9, and males in NGSS classes (n = 79) had a mean score of M = 40.0, with a standard deviation of SD = 6.5. Students enrolled in non-NGSS school districts (n = 120) had a mean score of M = 37.5 for Overall STEM Interest out of a possible 55, with a standard deviation of SD = 5.8. Females in non-NGSS classes (n = 66) had a mean score of M = 37.4, with a standard deviation of SD = 5.8, and males in non-NGSS classes (n = 54) had a mean score of M = 37.6, with a standard deviation of SD = 5.8. The confidence interval was set at 95% and produced a lower limit of 36.0 and an upper limit of 39.2 for the total STEM-CIS mean based on this sample (Warner, 2013).

Table 17

Descriptive Statistics for Female and Male Students in NGSS and Non-NGSS Classes on the STEM-CIS

	Gender	Standard Type	*M*	*SD*	*N*
Overall STEM	Female	NGSS	38.7	5.9	94
		Non-NGSS	37.4	5.8	66
		Total	38.1	5.9	160
	Male	NGSS	40.0	6.5	79
		Non-NGSS	37.6	5.9	54
		Total	39.0	6.3	133

The results of the MANOVA were not statistically significant, $F(293) = 2.68$, $p = .440$, $\eta^2 = .00$, observed power = .12 (Table 18; Warner, 2013). The null hypothesis was not rejected. The results demonstrate that a difference in STEM interest does not exist between male and female students in the sample population who attended schools implementing the NGSS and students in the sample population who attended schools that used traditional Pennsylvania science standards. The descriptive statistics indicate that male and female students in NGSS schools had similar interest toward STEM compared to male and female students enrolled in non-NGSS schools.

Table 18

MANOVA Results for Female and Male Students in NGSS and Non-NGSS Classes

Tests of between-subjects effects				
	Dependent Variable	*F*	Significance	Partial Eta Squared
Gender*Standard Type	Overall STEM	.60	.440	.00

Wilks' Λ was examined for a statistically significant difference between the dependent variables: interest toward science, technology, engineering, mathematics, and overall STEM interest. The Wilks' Λ was determined to be $p < .001$, indicating that there is a difference between groups on the dependent variables.

CHAPTER FIVE: CONCLUSIONS

Overview

The present study utilized a two-way MANOVA to determine whether students in school that have adopted the NGSS have significantly different interest in STEM compared to students enrolled in science classes in school districts utilizing traditional state standards. Results were collected from a sample population of 293 students from four high schools in Pennsylvania in which Grade 9 and Grade 10 students self-reported their interest in STEM disciplines. The sample population encompassed 94 females and 79 males enrolled in schools utilizing the NGSS and 66 females and 54 males in schools using traditional state standards.

Discussion

The purpose of the present study is to address a gap in the literature to determine whether students in public school classrooms utilizing the NGSS have a higher level of interest in STEM disciplines compared to students attending schools implementing traditional state standards, with a specific emphasis on the potential differences between genders. The study asked whether there is a difference between students' interest scores in science, technology, engineering, mathematics, and overall interest in STEM, as measured by the STEM-CIS, when enrolled in schools that have adopted the NGSS as compared to those enrolled in schools that have not.

Differences in Interest Based on Standards Type

The results of the present study indicate that, based on the type of standards utilized by the school district, there is a significant difference between student interest in overall STEM and the specific areas of science and technology. The results also demonstrated no difference in student interest in engineering or mathematics based on science standard type. Based on the sample population, students attending school districts that utilized the NGSS had a higher overall interest in science compared to students in schools that utilized the traditional Pennsylvania science standards, which are not NGSS aligned. The results follow trends found in previous studies. The NGSS were largely based on the recommendations of the NRC's 2012 *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, which highlighted best practices in science, emphasizing authentic experiences and cross-curricular experiences (REL, 2014). The *Framework* recommends STEM education that is rooted in real-world tasks and can make connections across both science and non-science disciplines (NRC, 2012). These methods are echoed by other researchers who have found that authentic STEM experiences not only help children to understand robust content but also lead to increased interest in STEM (Bethke et al., 2013; Farland-Smth & Tiarani, 2016). Similarly, the science subscale displayed the greatest difference in student interest between the four subscales, and results indicated that the NGSS have a significant impact on student interest in science. Students in the NGSS group reported higher interest in science, with the most significant effect size of $\eta^2 = .049$.

Interestingly, students enrolled in NGSS science classes also had higher statistically significant scores on the technology subscale, although scores for interest in technology were notably higher for both groups, regardless of standard type. The increased interest in technology is echoed by results found in a similar study. In a study conducted by Donmez and Idin (2020), when asked about their interest level in STEM fields, middle school students indicated that they were only interested in careers in technology. Increased interest in technology follows societal trends. A 2018 Pew Research Center report indicated that 95% of U.S. teenagers report either owning a smartphone or having access to one (p. 8), with 45% describing themselves as being online "almost constantly" and another 44% stating they are online "several times a day" (p. 9). As this time spent on devices accumulates, McNaughton and Glickman (2018) report that teenagers spend upwards of 11 hours per day engaged in media technology. The near constant access to technology, however, has led to an increased flexibility and comfort with technology not seen in previous generations (Hranovska, 2020). A recent study indicates that students prefer to use technology more holistically in their lives, including in their classes at school (Hranovska, 2020). Data from recent AP exams support this research. The number of students who took the AP Computer Science Principles exam doubled from 2017 to 2019, with nearly 100,000 taking the exam in 2019 (College Board, 2019).

While a significant difference could be identified regarding interest in both science and technology based on the standard type, results for the engineering and mathematics subscales were found to not have a statistically significant difference. Although students in the NGSS group rated their interest in engineering higher than students in the non-NGSS group, the difference was only marginal, amounting to $p = .051$ with $a = .05$, rendering the results statistically insignificant. With a p value of $p = .051$, the results were 0.001 away from being significant. In addition, the engineering subscale had the lowest reported scores for both groups. Because the NGSS is relatively new, research on this phenomenon is sparse. Similar studies suggest, however, that teachers maintain positive intentions, but struggle to effectively implement engineering in science classes (Carpenter et al., 2019; Hammack & Ivey, 2019; Kaya et al., 2019). The results of this study suggest a need for further investigation into the effects of the NGSS on interest in engineering.

With mathematics, there was virtually no difference between the scores on the STEM-CIS based on standard type. Students in both groups reported almost equal interest in mathematics. These results align with findings in previous research. A meta-analysis of research into the effects of STEM programming on mathematics found that 13 out of the 16 studies reviewed produced only a small effect size (Siregar et al., 2020). Other researchers have indicated that math has received neither the research attention nor the implementation attention it requires as an equal component of STEM education and have advocated for increased mathematics in integrated STEM (Costa & Domingos, 2019; Stohlmann, 2018). Speculation based on previous research (see Carpenter et al., 2019; Costa & Domingos, 2019; Hammack & Ivey, 2019; Kaya et al., 2019; Siregar et al., 2020; Stohlmann, 2018) would suggest the findings related to engineering and mathematics interest could be related to the methods used for implementing engineering and mathematics into science courses to create a true STEM experience. However, further investigation into the specific effects of the NGSS on engineering and mathematics interest is necessary.

Differences in Interest Based on Gender

The data indicated that there was not a statistically significant difference in overall interest in STEM between male and female students. Out of a possible score of 55, male students had an average overall interest score of $M = 39.004$ and female students had an average score of $M = 38.148$. Much of the research conducted to date has outlined the stark differences between male and female interest in STEM (Cunningham et al., 2015; Evans et al., 2020; Kerr, 2016; Valenti et al., 2016), rendering this study dissimilar to past research. Although specific reasons for the divergence of this study's results from earlier research is difficult to pinpoint, data from previous studies suggest it may be related to teacher attitude and pedagogy. Researchers have identified factors such as access to role models (Beede et al., 2011; Swafford & Anderson, 2020), communication concerning STEM career interests and support (Jackson et al., 2019; Swafford & Anderson, 2020), the inclusion of female interests (Hasni, 2015; Swafford & Anderson, 2020), the development of self-efficacy (Phelan et al., 2017; Tellhed et al., 2017), and the presence of a growth mindset (Vervaeke & Ferraro, 2013) as valuable tools for developing interest in STEM among female students.

While the results of this study contrast to a considerable body of research, they do not stand alone. A recent study drew similar conclusions to those in the present study. When other factors were controlled, female students were equally likely to be interested in and remain interested in STEM disciplines in comparison to their male peers (Status et al., 2020). In other words, when students began with a high interest in STEM, their interest remained high, but when students had a low interest in STEM, their interest continued to decline over time. The researchers indicated that their results were “in line with others who have reported that comparisons based on gender tend to exaggerate differences between the sexes while failing to recognize the diversity of interests within each group” (Status et al., 2020, p. 9). Studies have shown that all students, regardless of gender, who are already interested in STEM can benefit from a growth mindset and the use of incremental belief systems to support their own self-perceptions and increase their interest (Lytle & Shin, 2020).

Because research has consistently demonstrated that female interest in STEM decreases over time as students approach and graduate from high school (Catsambis, 1995; Cunningham et al., 2015; Evans et al., 2020; Kerr, 2016; Shymansky & Kyle, 1988; Simpson & Oliver, 1990; Weinburgh, 1995), the data suggests these female students with interest nearly equal to that of their male peers have a high likelihood of maintaining their interest in STEM. For the female students involved in this study, this becomes even more critical when considering the role that interest has on female career trajectories. The interest of female students in early high school years can be a major predictor of later career and college choices (Weeden et al., 2020). While the current study did not examine interest in specific careers, research suggests that interest plays a greater role in female career decisions than it does for male students (Wang et al., 2017).

Interaction Between Gender and Standard Type

There was no statistically significant difference in the interest in STEM overall between male and female participants when analyzed based on standard type, with a significance value of $p = .440$. However, when the data was examined for individual subscales, several trends became visible. Female students in the NGSS group scored highest on the science subscale across all groups, indicating science as the area of STEM in which they have the most interest, with technology close behind. Females in the Non-NGSS group scored highest across all groups on the mathematics subscale. Compared to the male scores, the interest scores for female students have significantly more variability. One explanation for this was recently discussed in another study, which suggested that female students are less likely to see STEM holistically, instead viewing the individual components of STEM as separate fields of interest (Naukkarinen, & Bairoh, 2020). For example, a female student may express interest in science, but that same level of interest is unlikely to apply to engineering or technology (Naukkarinen, & Bairoh, 2020).

Females in both groups scored lowest on the engineering subscale. The low scores for females on the engineering subscales are part of a body of research that has demonstrated inconsistent engineering interest scores for girls. Several studies have revealed that girls score lower in engineering interest than their male peers (Hirsch, 2007; Status et al., 2020), while others have failed to find that difference (Donmez & Idin, 2020).

Male students in both groups scored highest on the technology subscale. The male students in the non-NGSS group scored lowest on the science subscale. Although the male students in the NGSS group scored lowest on the engineering subscale, it was by a small margin, with all subscale scores other than technology being nearly equivalent.

Table 19

Scores for Individual Subscales on the STEM-CIS

	Female		Male	
	StanType	Mean	StanType	Mean
Science	NGSS	40.8	NGSS	38.8
	Non-NGSS	39.0	Non-NGSS	33.5
Technology	NGSS	40.2	NGSS	43.2
	Non-NGSS	39.1	Non-NGSS	40.0
Engineering	NGSS	35.0	NGSS	38.7
	Non-NGSS	31.2	Non-NGSS	38.0
Mathematics	NGSS	38.8	NGSS	39.2
	Non-NGSS	40.4	Non-NGSS	38.8
STEM Overall	NGSS	38.7	NGSS	40.0
	Non-NGSS	37.4	Non-NGSS	37.6

Implications

The results of this study add to a body of research that highlights the need for hands-on, authentic learning for students in science. While the results of this study suggest a closing gender gap regarding science interest within the sample population, they also underscore the importance of practical, authentic learning experiences for students in science. Both male and female students in the NGSS group self-reported higher interest in STEM compared to students in the non-NGSS group, with the greatest differences found within the science subscale. This implies that there is a relationship between the NGSS and higher student interest in STEM overall and, specifically, science. However, the results of this study also imply that the impact of standard type on STEM disciplines is not universal. Mathematics did not appear to have a statistically significant difference between the two standard type groups. Meanwhile, the engineering subscale produced a near-significant result. Further research is needed to identify methods of increasing student interest in engineering and mathematics, with a particular focus on the gender gap that may exist concerning interest in engineering.

As states continue to evaluate their science standards, this study, as well as an ever-expanding body of research, suggests the hands-on and cross-curricular experiences that mimic real-world application and that exist within the NGSS are beneficial in increasing both male and female interest in STEM. State standards are only one piece of the science-education puzzle, however. This study was conducted in Pennsylvania, which does not officially utilize the NGSS. The schools labeled as NGSS schools in the study purposefully selected curricula that align with the NGSS. Therefore, the responsibility lies not only on the states to implement standards that align with best practices, but on school districts to select curricular materials and supplemental resources that uphold the goals outlined in the NRC's *Framework* (2012).

Limitations

The greatest limitation to this study was the environment in which it was conducted. This study occurred during the COVID-19 pandemic, which greatly altered the methods teachers were able to use to engage students in STEM learning. It is possible that the pandemic and the subsequent lack of hands-on learning experienced by these students over the prior months impacted their interest in STEM.

In addition to the challenges presented during the pandemic, more common limitations also existed. For example, the sample population was one limitation to the results of this study. Many school districts prohibit outside data collection, artificially decreasing the pool of participants and limiting the ability to match school districts based on demographic criteria. Classroom selections and student participants were limited to students who chose to partake in the study, which may have had an impact on the results as well. These factors all decrease the generalizability of this study to a larger population. This study was conducted in suburban settings in Western Pennsylvania. Further research is required to determine whether the same results can be found across different states and settings.

A causal-comparative research design was used for the present study, which presents additional limitations. Causal comparison studies produce data with which the researcher can infer the relationship between variables, but stops short of identifying causation (Gall, Gall, & Borg, 2007). To further determine the effects of standard type on student interest in STEM, an experimental or quasi-experimental study is recommended.

The present study examined the impact of the NGSS on student interest in science. Given that the NGSS rely heavily on authentic, applicable experiences and cross-curricular connections, teaching style remains a major limiting factor in this study. Teachers in schools that utilize the traditional Pennsylvania science standards may indeed use many of the methods found in the NGSS. Similarly, teachers in school districts implementing the NGSS may have teachers who choose to utilize older materials that do not align to the NRC *Framework* (2012).

As with many Likert-style self-report measures, response bias presents an additional limitation of the study. In particular, bias due to acquiescence is particularly relevant. Researcher Delroy Paulhus (1991) described acquiescence as the "tendency to agree rather than disagree" with survey response items (p. 48). Some participants, by nature, are more likely to respond "yes" while others are more likely to respond "no" on self-report measures, which can alter data (Paulhus, 1991).

Recommendations for Future Research

1. It is recommended that future research investigate the role of mathematics and engineering related to STEM and how students develop interest in these two fields. The present study revealed that standard type had no impact on math interest. Considering math is a major component of STEM education, a question remains concerning whether students make the connection between math and STEM through their experiences in science class.
2. The engineering subscale results were nearly significant. Additional research is necessary regarding the impact of the NGSS and other standards on student interest in engineering.
3. Female students who participated in this study scored lower than male students on the engineering subscale. Future research identifying methods of increasing girls' interest in engineering is still needed.

4. The causal-comparative design of this study produced significant limitations. An experimental or quasi-experimental study on the impact of science standard type on student interest in STEM is therefore recommended.

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Appendix A

Instrument Permission

Figure A1

Instrument Permission

[External] Re: Permission to use STEM-CIS

MB

Margaret Blanchard <[redacted]>
Tue 11/12/2019 1:27 PM
To: May, Brienne Kylie; Kier, Meredith [redacted]
Cc: Wendt, Jillian Leigh (Doctor of Education); [redacted]

[EXTERNAL EMAIL: Do not click any links or open attachments unless you know the sender and trust the content.]

Dear Brienne,

I know I speak for Meredith Kier and my co-authors that we would love to have you use the STEM-CIS and grant you permission to use what is needed in your dissertation study. We wish you the very best in your work.

Thanks,
Meg

...

Margaret R. Blanchard, PhD

Professor of Science Education & University Faculty Scholar
Associate Department Head & Director of Graduate Programs, STEM Education
Graduate Coordinator, Science Education

[redacted]

Act as if what you do makes a difference. It does.
- William James

Reply | Reply all | Forward

Appendix B

Letter to Participating Schools

Brienne May

Doctoral Candidate

Liberty University

Request for Permission to Conduct Survey Research in Schools

Dear ______,

My name is Brienne May and I am an Ed.D. candidate at Liberty University in Lynchburg Virginia. The research I wish to conduct for my dissertation involves the potential effects of science standards on student interest in science. This research will be conducted under the supervision of Dr. Wendt of Liberty University.

I am seeking your consent to digitally administer a 44-question, Likert-style survey to volunteers enrolled in 9th and 10th grade science. The research could be conducted in a single class period on any device. Surveys will be sent to participating teachers via Google Forms and responses will be collected anonymously. All schools participating in the research will be identified only as NGSS or non-NGSS schools based on the standards for each state. The research will take place between May and October 2020.

I have provided you with a copy of my dissertation proposal as well as copies of the consent and assent forms to be used in the research process as well as a copy of the approval letter which I received from the Liberty University Institutional Review Board.

Appendix C

Parental Consent and Opt-Out Form

Title of the Project: A Comparison of Students' Interest in STEM Across Science Standard Types
Principal Investigator: Brienne May, Doctoral Candidate, Liberty University

Invitation to be Part of a Research Study

Your student is invited to participate in a research study. Participants must be a 9th grade or 10th grade student enrolled in a science class. Taking part in this research project is voluntary.

Please take time to read this entire form and ask questions before deciding whether to allow your student to take part in this research project.

What is the study about and why are we doing it?

The purpose of the study is to learn whether the type of science standard used by school districts has an impact on student interest in science and STEM careers.

What will participants be asked to do in this study?

If you agree to allow your student to be in this study, I would ask him or her to participate in a ten-minute multiple-choice survey about his or her interest in STEM. The survey can be accessed on any device with internet access. Your child's teacher will administer the survey digitally.

How could participants benefit from this study?

Participants should not expect to receive a direct benefit from taking part in this study.

What risks might participants experience from being in this study?

The risks involved in this study are minimal, which means they are equal to the risks your student would encounter in everyday life.

How will personal information be protected?

The records of this study will be kept private. Research records will be stored securely, and only the researcher will have access to the records. Participant responses will be kept anonymous. School districts will be identified only by the type of science standard used. Data will be stored on a password-protected external hard drive. The data will be kept for three years following the conclusion of the study. After three years, all electronic records will be deleted.

Is study participation voluntary?

Participation in this study is voluntary. Your decision whether or not to allow your student to participate will not affect your or his or her current or future relations with Liberty University. If you decide to allow your student to participate, she or he is free to not answer any question or withdraw at any time prior to submitting the survey without affecting those relationships.

What should be done if a participant wishes to withdraw from the study?

If you choose to withdraw your student from the study or your student chooses to withdraw from the study, please have him or her exit the survey and close her or his internet browser. Your student's responses will not be recorded or included in the study.

Whom do you contact if you have questions or concerns about the study?

The researcher conducting this study is Brienne May. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact her at [redacted] or [redacted]. You may also contact the researcher's faculty sponsor, Dr. Jillian Wendt, at [redacted].

Whom do you contact if you have questions about rights as a research participant?

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Institutional Review Board, [redacted] or email at [redacted]

Your Consent

Before agreeing to allow your student to be part of the research, please be sure that you understand what the study is about. If you agree to allow your student to participate in the study, no further action is needed. If you have any questions about the study, you can contact the study team using the information provided above.

Opt-Out

If you **do not** want your child to participate in the study, please sign the form below and return it to your child's school. **By signing this document, you are withdrawing your student from this study.** You will be given a copy of this document for your records. The researcher will keep a copy with the study records.

I have read and understood the above information. I have asked questions and have received answers. I am withdrawing my student from participation in the study.

____
Printed Student's Name

____
Parent's Signature   Date

Appendix D

Student Assent to Participate in a Research Study

What is the name of the study and who is doing the study?

The name of the study is A Comparison of Students' Interest in STEM Across Science Standard Types, and the person doing the study is Brienne May.

Why is Brienne May doing this study?

Brienne May wants to know if the different types of science standards used in Pennsylvania schools have an effect on student interest in STEM.

Why am I being asked to be in this study?

You are being asked to be in this study because you are a 9th or 10th grade student enrolled in a science course in a public high school in Pennsylvania.

If I decide to be in the study, what will happen and how long will it take?

If you decide to be in this study, you will be asked to participate in a survey that will take approximately 10 minutes to complete. The survey will ask you about your interest in STEM using multiple choice questions. The survey will be taken on a device with internet access.

Do I have to be in this study?

No, you do not have to be in this study. If you want to be in this study, then tell the researcher. If you don't want to, it's OK to say no. The researcher will not be angry. Participation in the survey will have no effect on your grade. You can say yes now and change your mind later. It's up to you.

What if I have a question?

You can ask questions any time. You can ask now. You can ask later. You can talk to the researcher. If you do not understand something, please ask the researcher to explain it to you again.

Brienne May

[redacted]

Dr. Jillian Wendt

[redacted]

Liberty University Institutional Review Board

[redacted]

If you agree to participate in the study, please click the button below.

Appendix E

STEM-CIS Administration Guidelines

(Kier et al., 2014)

Thank you for your participation in this research survey! Please review the following guidelines for administration of the STEM Career Interest Survey.

1. Students will take the survey on a device that has access to the internet.
2. You will be provided with a script to read before students begin the survey.
3. After reading the script, you will have the opportunity to answer any student questions.
4. Participation in the survey does not affect student grades in any way, including offerings of extra credit.

Appendix F

STEM-CIS Administration Script

(Kier et al., 2014)

Today our class will be taking part in a brief research survey regarding your interest in science, technology, engineering, and math. This survey has no impact on your grade and participation is completely optional. All data obtained from this survey is anonymous. You have the option to agree to decline to participate in this survey which will take approximately 10 minutes. The survey will be taken on your computer/tablet/smart phone. If you agree to participate in the survey, please indicate that you agree on the first page of the survey.

Before I send you the link to the survey, let's start with a sample item. This will give you an idea of what the questions will look like and how to answer them.

Display the following:

Pizza is a good food to have for breakfast.

1. Strongly Disagree

2. Disagree

3. Neither Agree nor Disagree

4. Agree

5. Strongly Agree

For the survey, you will select one of the choices to indicate how you feel about the statement. "Pizza is a good food to have for breakfast." Do you strongly disagree, disagree, neither agree nor disagree, agree, or strongly agree? You will select the option that best describes your opinion. Are there any questions about how to answer the survey items?

Answer any questions students may have. Share the link to the survey with the class. This may be done via LMS (Google Classroom, Blackboard, MOODLE, etc.) or school email.

You may now begin the survey. When you are done, submit the survey.

Appendix G

Family Recruitment Letter

Dear students and parents:

As a graduate student in the School of Education at Liberty University, I am conducting research as part of the requirements for a doctoral degree. The purpose of my research is to better understand how science standards affect students' interest in STEM, and I am writing to invite eligible participants to join my study.

Participants must be in 9th or 10th grade and enrolled in a science course. Participants, if willing, will be asked to take a brief survey. It should take approximately ten minutes to complete. Participation will be completely anonymous, and no personal, identifying information will be collected.

A parent consent/opt-out document is attached to this email. The consent document contains additional information about my research. You do not need to sign and return the consent document unless you do not want your child to participate in the study

In order for your child to participate, he or she will be given a link to access the survey. A student assent form is provided on the first slide of the survey. After students have read the assent form, they will click a button to proceed to the survey. Doing so will indicate that your child has read the assent information and would like to take part in the survey.

Sincerely,

Brienne May
Liberty University Graduate Student
[redacted]

Appendix H

IRB Approval Letter

September 2, 2020

Brienne May

Jillian Wendt

Re: IRB Approval - IRB-FY19-20-348 A Comparison of Students' Interest in STEM Across Science Standard Types

Dear Brienne May, Jillian Wendt:

We are pleased to inform you that your study has been approved by the Liberty University Institutional Review Board (IRB). This approval is extended to you for one year from the date of the IRB meeting at which the protocol was approved: September 2, 2020. If data collection proceeds past one year, or if you make modifications in the methodology as it pertains to human subjects, you must submit an appropriate update submission to the IRB.
These submissions can be completed through your Cayuse IRB account.

Your study falls under the expedited review category (45 CFR 46.110), which is applicable to specific, minimal risk studies and minor changes to approved studies for the following reason(s):

7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Your study involves surveying or interviewing minors, or it involves observing the public behavior of minors, and you will participate in the activities being observed.

Your stamped consent form and stamped assent form can be found under the Attachments tab within the Submission Details section of your study on Cayuse IRB. These forms should be copied and used to gain the consent of your research participants. If you plan to provide your consent information electronically, the contents of the attached consent and assent documents should be made available without alteration.

Thank you for your cooperation with the IRB, and we wish you well with your research project.

Sincerely,

G. Michele Baker, MA, CIP

Administrative Chair of Institutional Research

Research Ethics Office